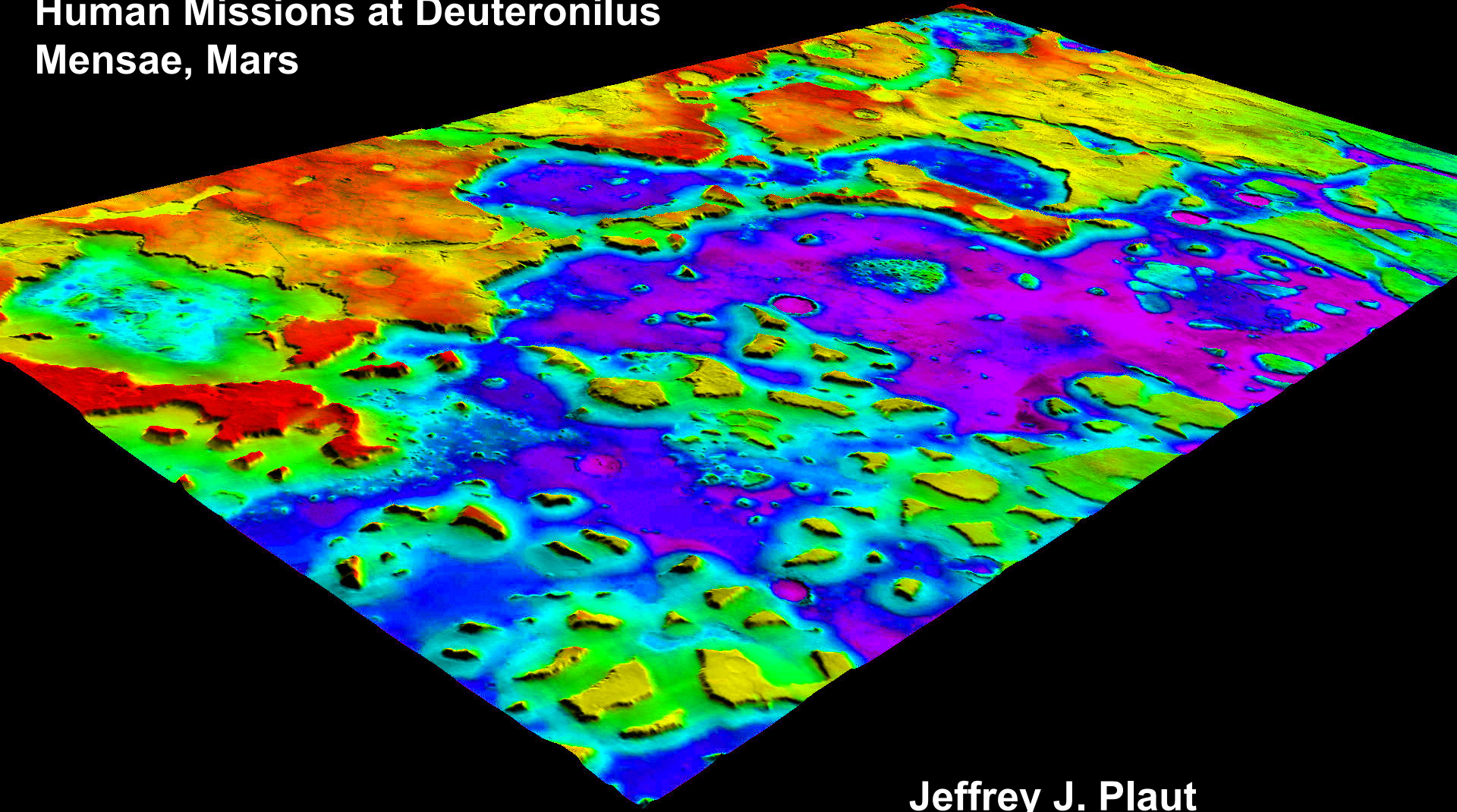
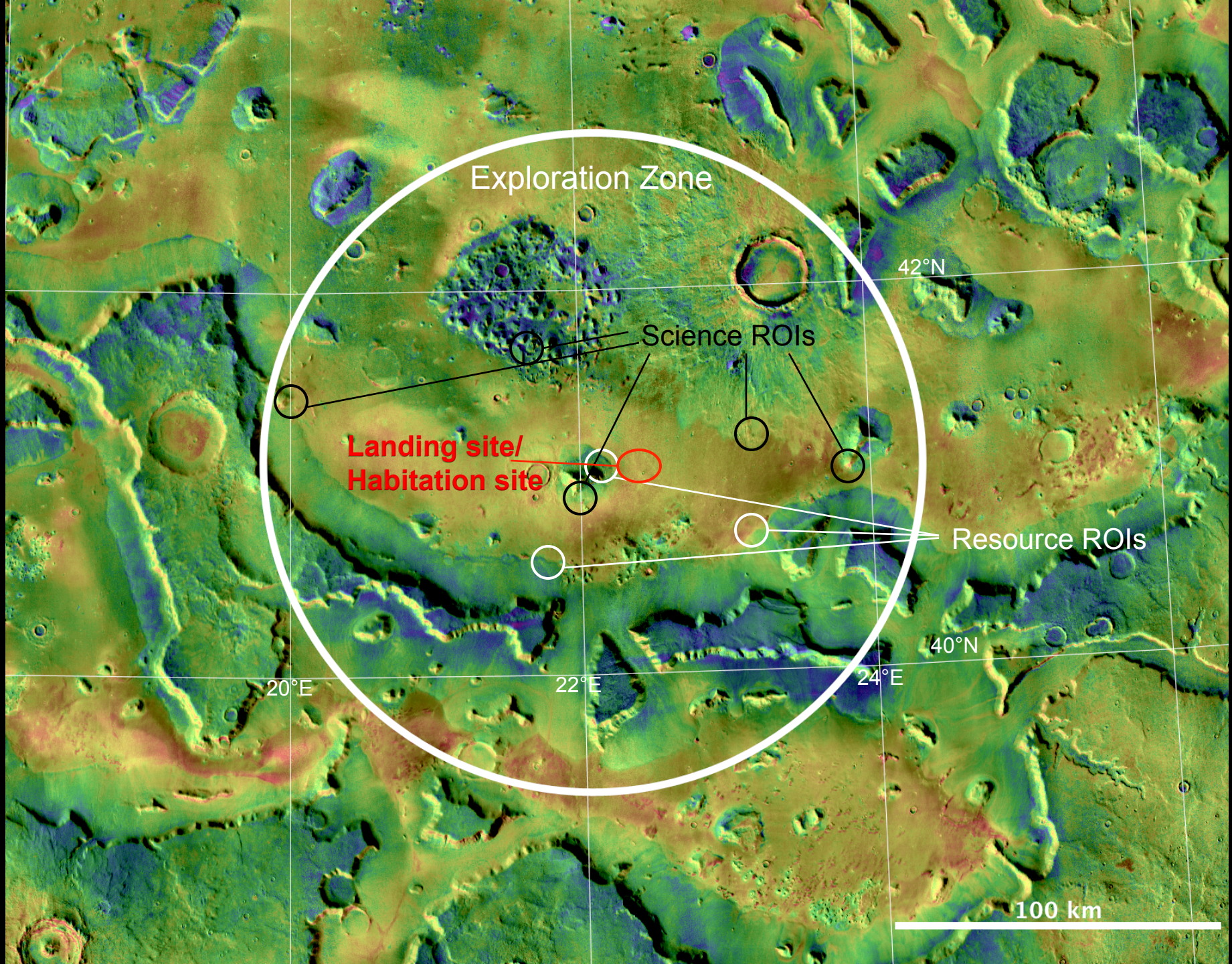


**A Resource-rich, Scientifically  
Compelling Exploration Zone for  
Human Missions at Deuteronilus  
Mensae, Mars**



**Jeffrey J. Plaut  
Jet Propulsion Laboratory / California  
Institute of Technology**







*Science* 21 November 2008:

## **Radar Sounding Evidence for Buried Glaciers in the Southern Mid-Latitudes of Mars**

John W. Holt,<sup>1\*</sup> Ali Safaeinili,<sup>2</sup> Jeffrey J. Plaut,<sup>2</sup> James W. Head,<sup>3</sup> Roger J. Phillips,<sup>4</sup> Roberto Seu,<sup>5</sup> Scott D. Kempf,<sup>1</sup> Prateek Choudhary,<sup>1</sup> Duncan A. Young,<sup>1</sup> Nathaniel E. Putzig,<sup>4</sup> Daniela Biccari,<sup>5</sup> Yonggyu Gim<sup>2</sup>

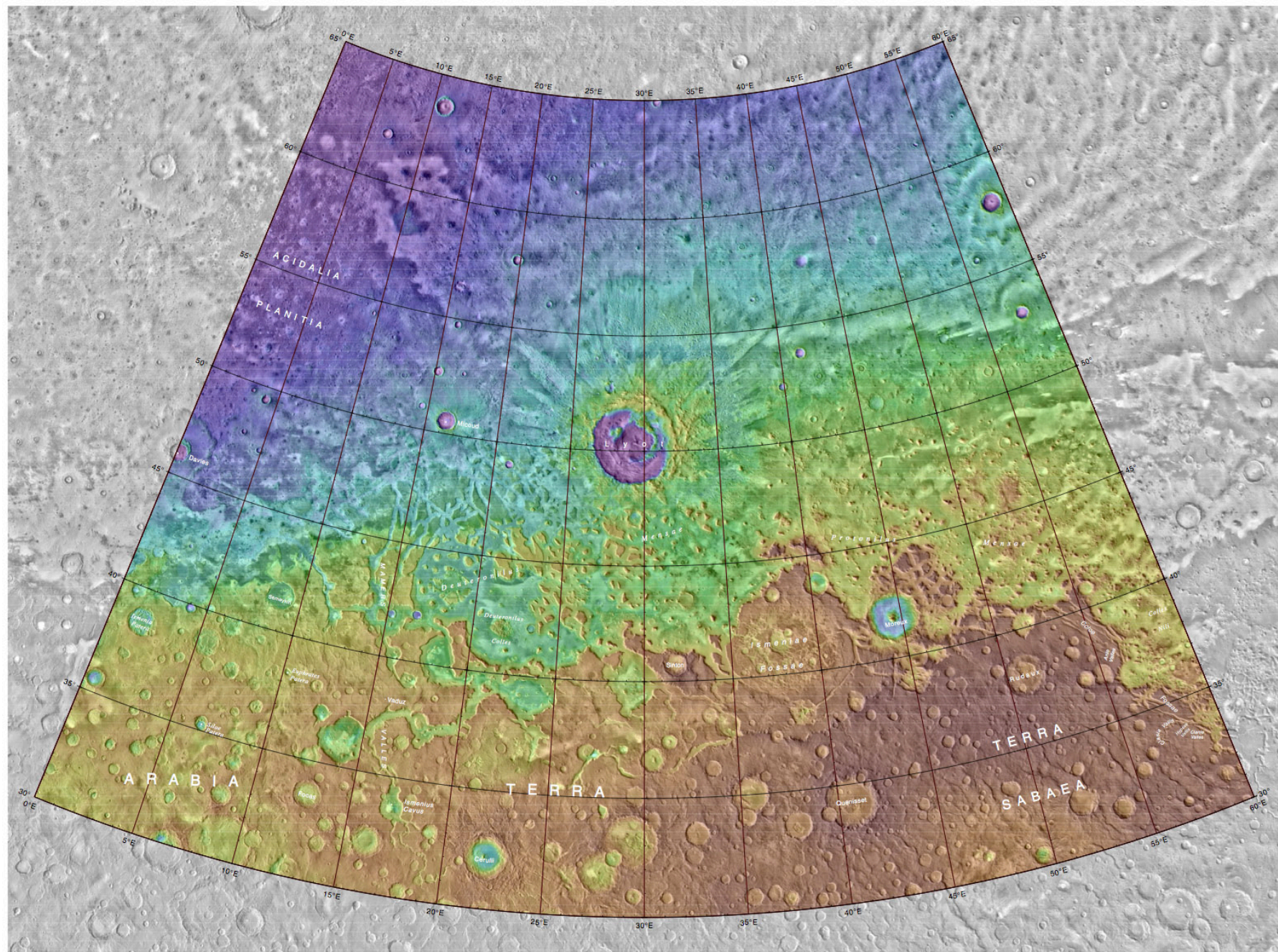
GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L02203, doi:10.1029/2008GL036379, 2009

## **Radar evidence for ice in lobate debris aprons in the mid-northern latitudes of Mars**

Jeffrey J. Plaut,<sup>1</sup> Ali Safaeinili,<sup>1</sup> John W. Holt,<sup>2</sup> Roger J. Phillips,<sup>3</sup> James W. Head III,<sup>4</sup> Roberto Seu,<sup>5</sup> Nathaniel E. Putzig,<sup>3</sup> and Alessandro Frigeri<sup>6</sup>

“Present-day thick ice deposits at the mid-latitudes of Mars should be considered as targets for future landed missions. If accessible, the ice could be analyzed for climatological indicators or biomarkers, and potentially be utilized as a resource.”





Projection: Lambert Conformal Conic  
 Datum: Mars 2000 Sphere  
 Central Meridian: 30.0  
 Standard Parallel 1: 36.2  
 Standard Parallel 2: 69.5  
 Scale Factor: 1.0  
 Latitude of Origin: 0.0

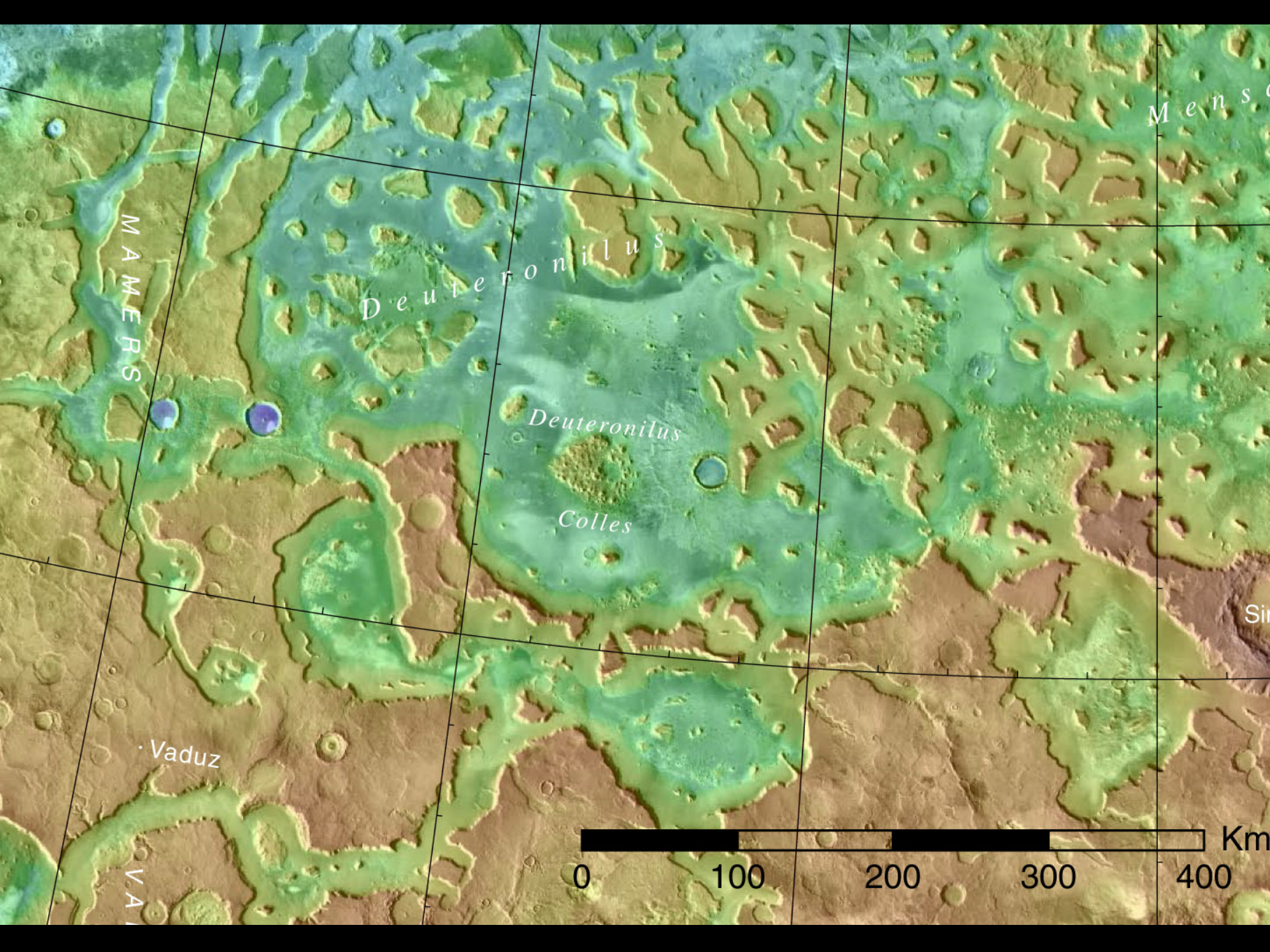
MOLA Elevation (m)  
 High : 1205  
 Low : -7013

0 100 200 300 400 Km  
 Scale 1:5,000,000 at standard parallel

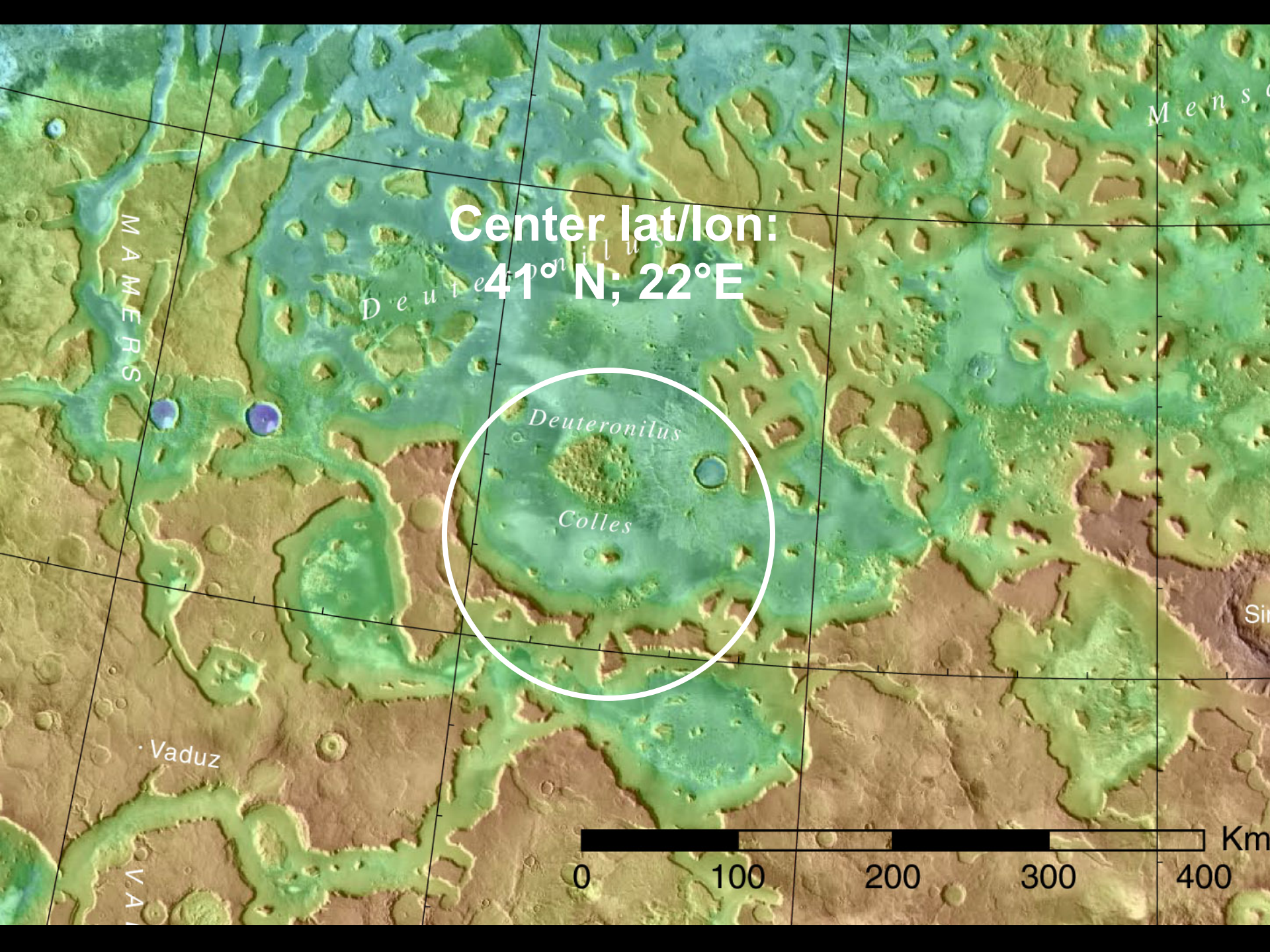
Ismenius Lacus, MC-5

Base image: THEMIS IR Day mosaic by ASU  
 Margin image: THEMIS IR Global Mosaic v11.6, ASU  
 Colorized Topography: MOLA Elevation Model, GSFC











Center lat/lon:  
**41° N; 22° E**

See, for example  
**Salt Lake City**  
**New York City**  
**Madrid**  
**Rome**

*Deuteronilus*

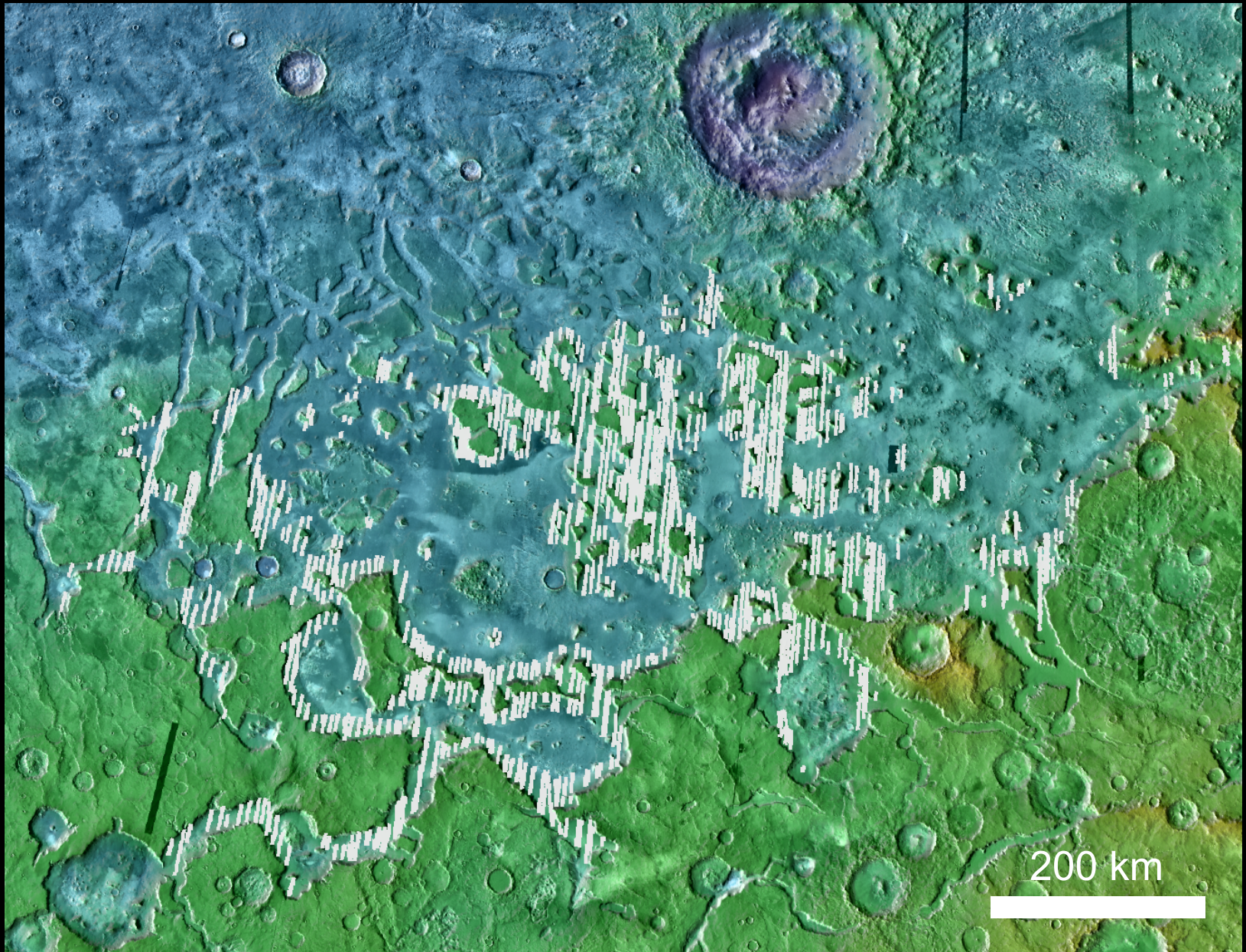
*Colles*

Vaduz

0 100 200 300 400 Km

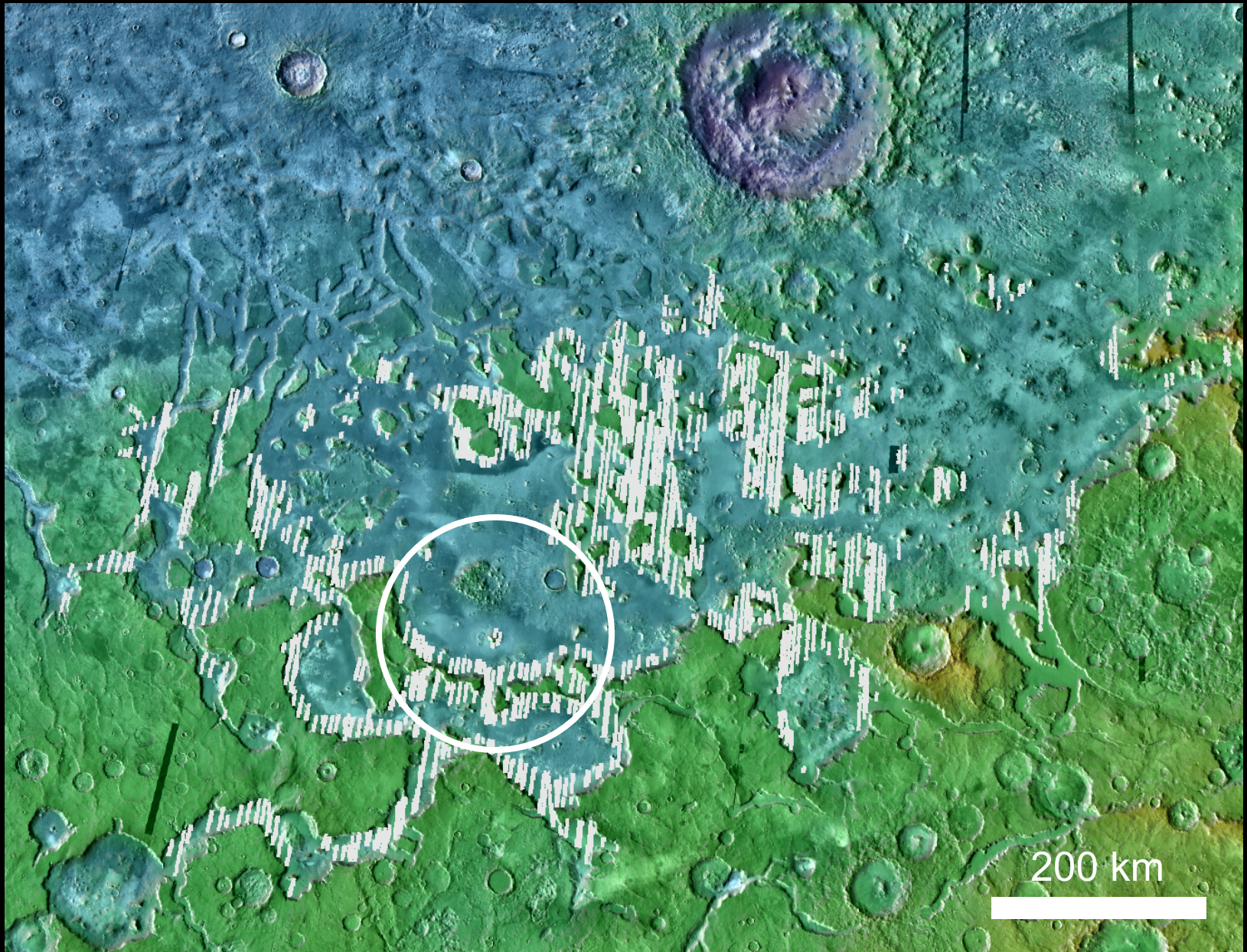


## Detections of Thick Ice in Deuteronilus





## Detections of Thick Ice in Deuteronilus





## Resource ROI 1 – Margin of Apron





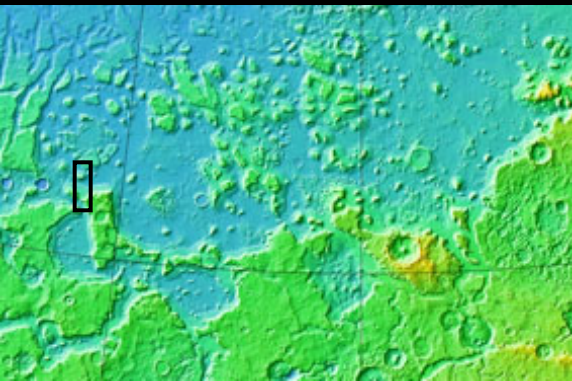
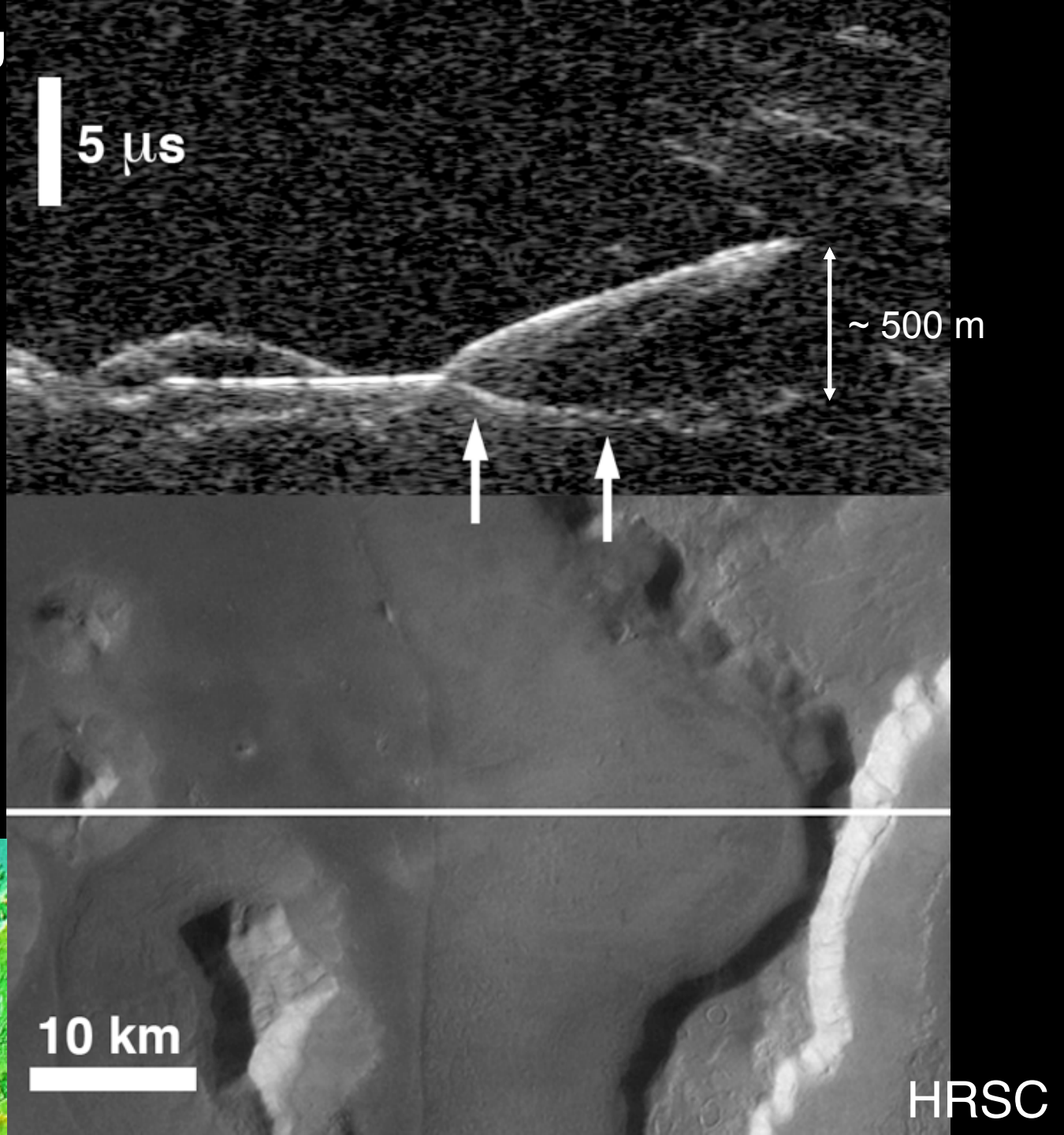
## Resource ROI 1 – Margin of Apron





# SHARAD Sounding of Lobate Debris Aprons

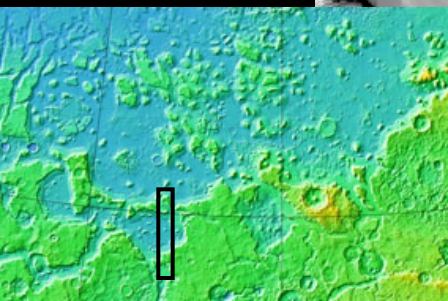
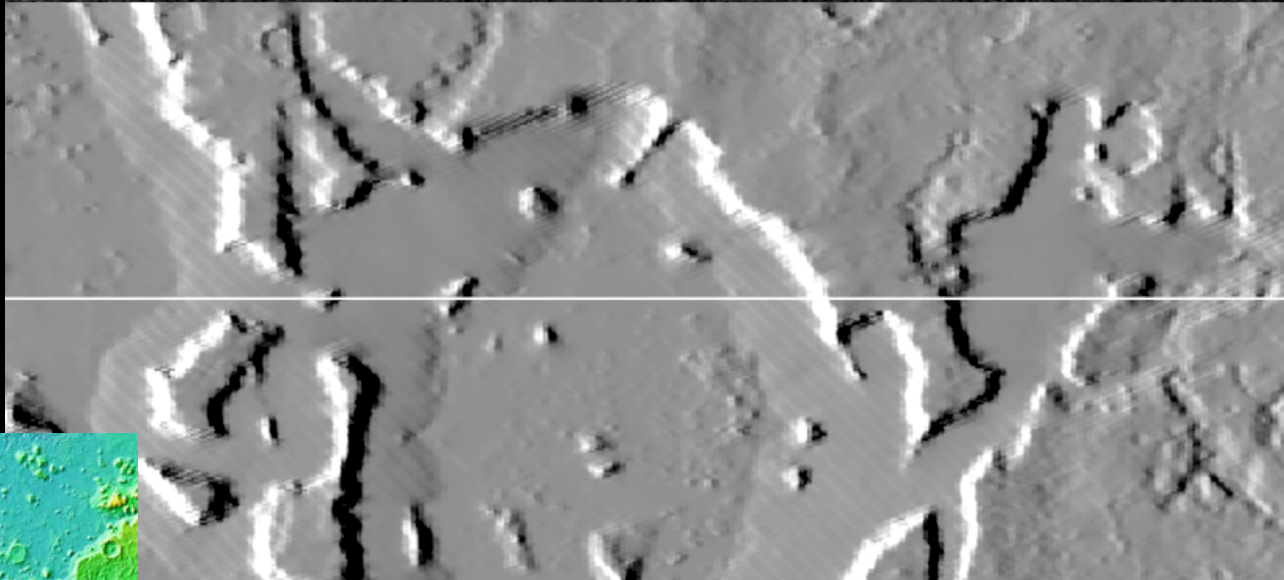
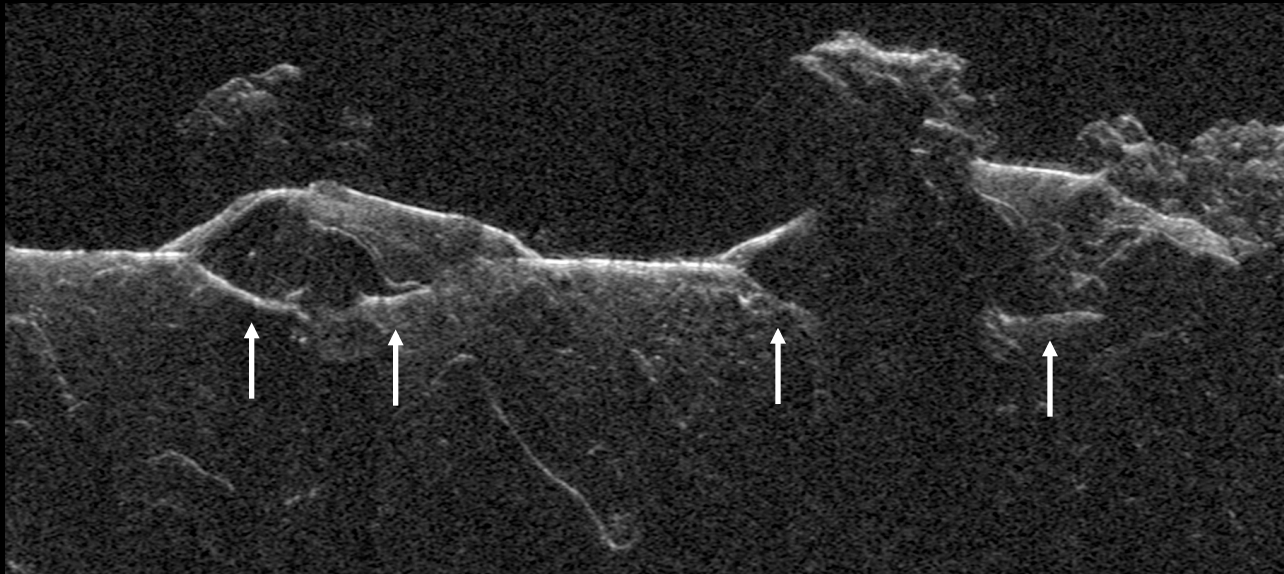
2145\_01





# Converting Time to Depth

Time

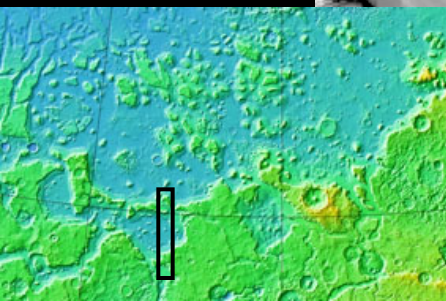
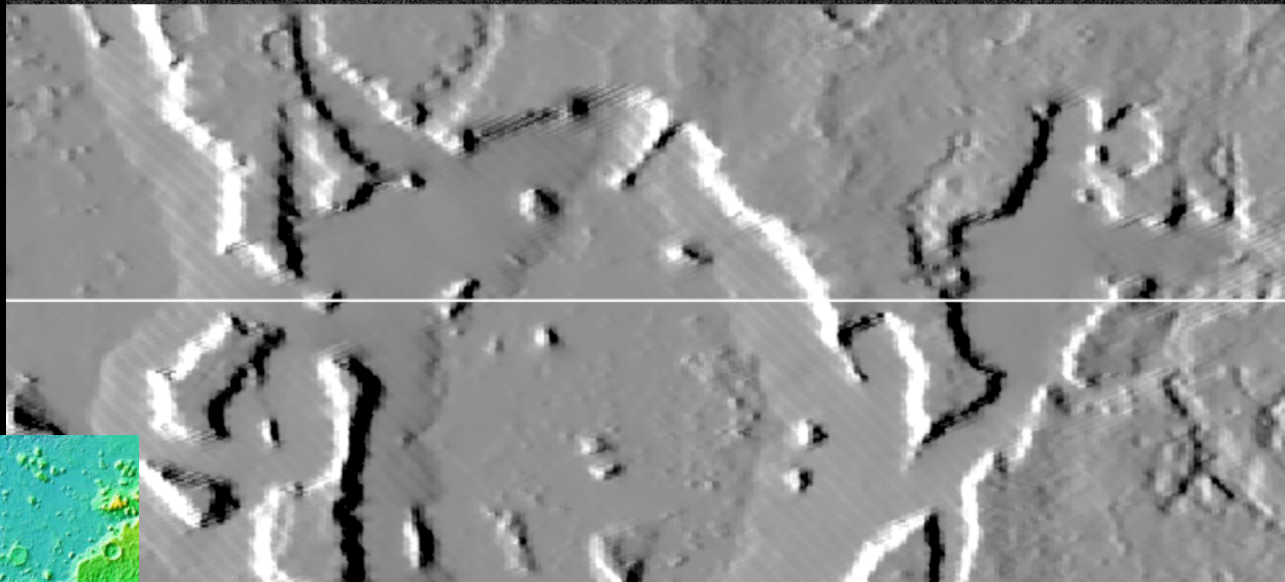
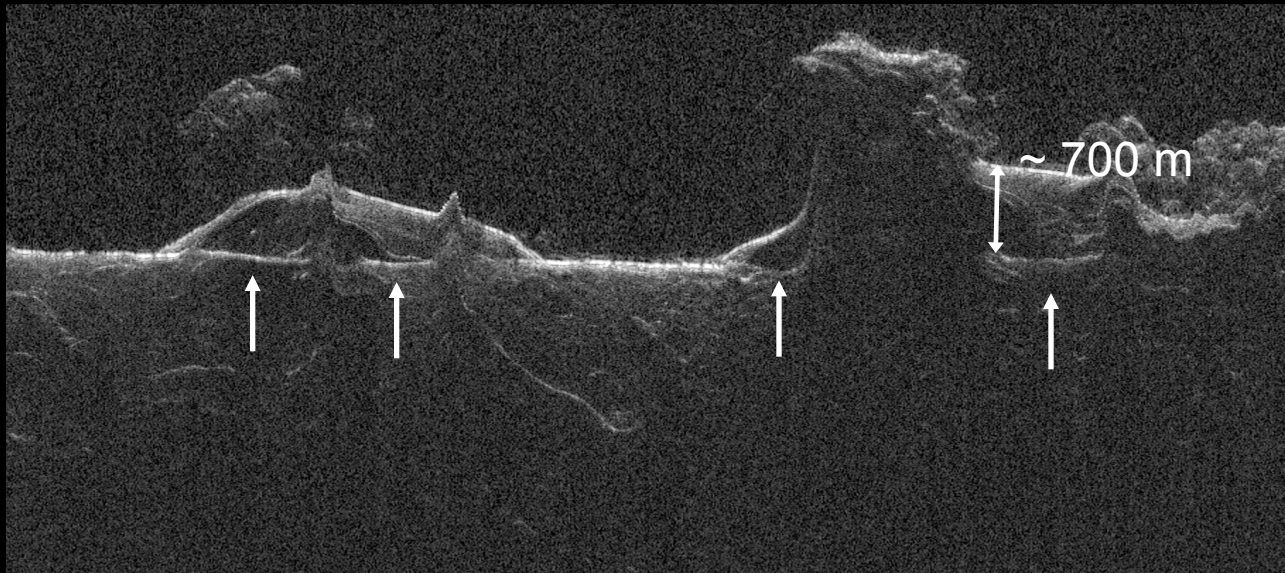


50 km



# Converting Time to Depth

Depth

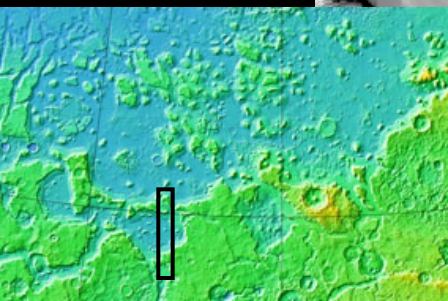
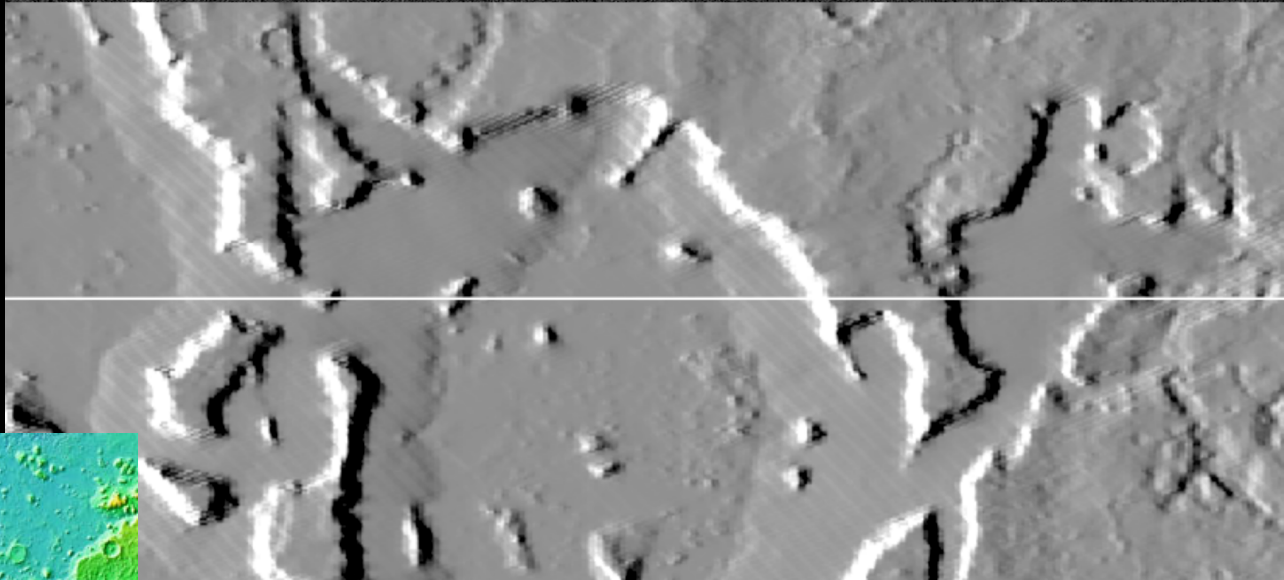
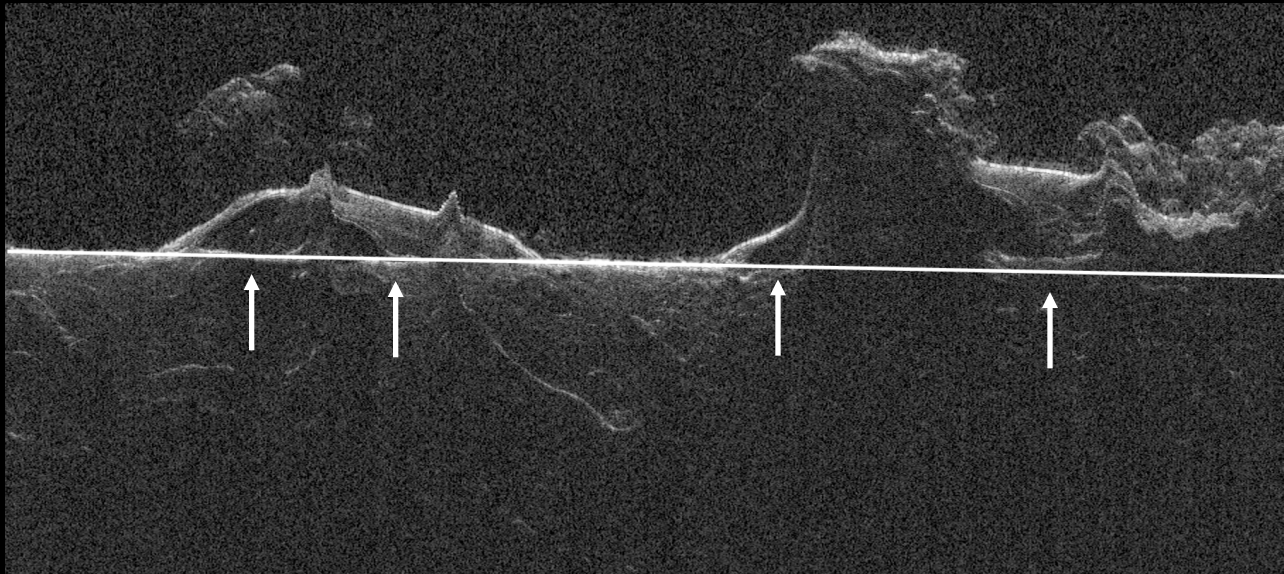


50 km



# Converting Time to Depth

Depth



50 km





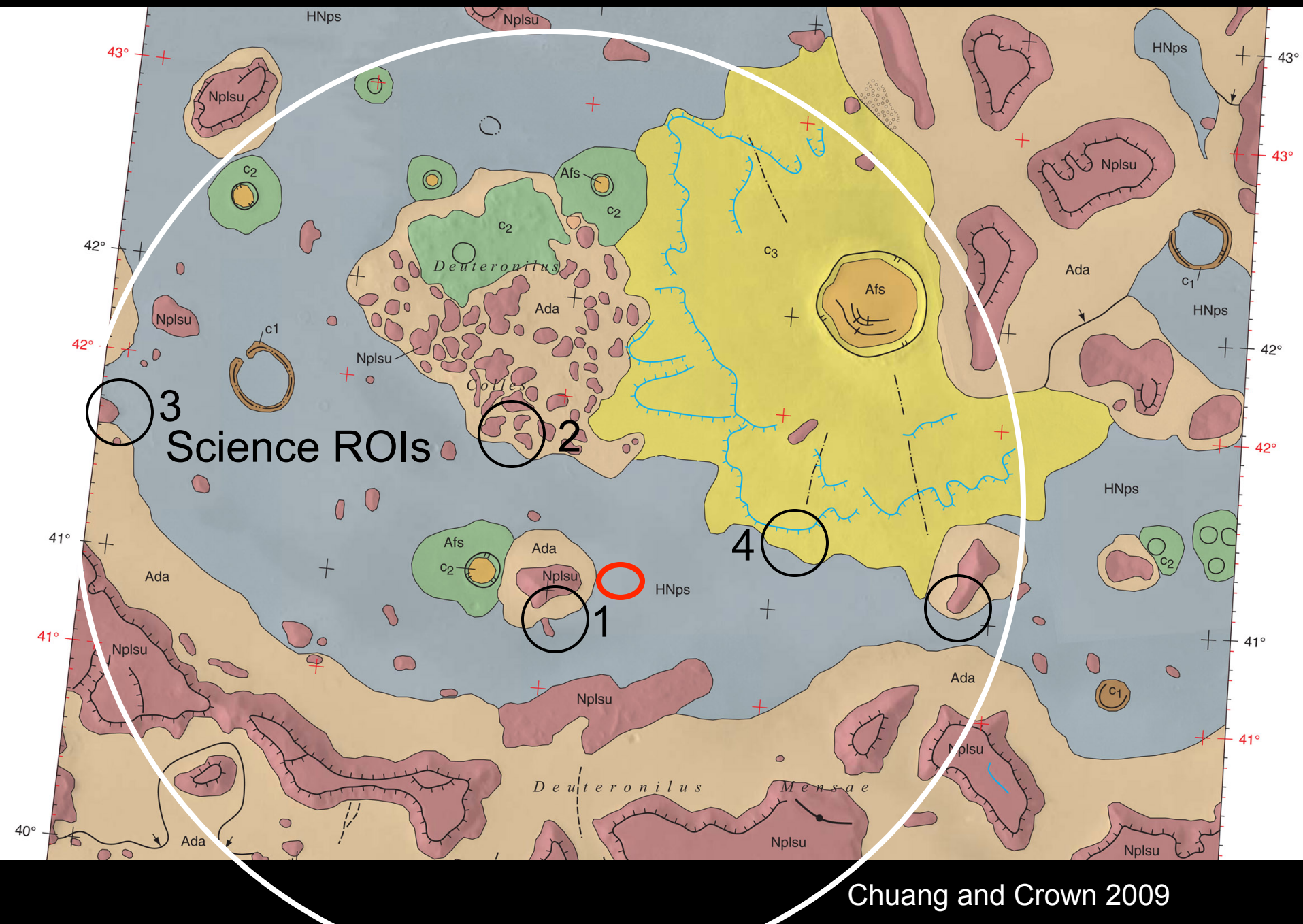
## Constraining the thickness of overburden (How deep is the top of the ice?)

- No enhancement in H content is seen in Odyssey GRS or Neutron data.
  - Implies that the upper 0.5-1.0 m is “dry”.
- No shallow boundary between dry overburden and massive ice is seen in SHARAD data. Implies either:
  - a) boundary is in the near-surface blind zone (~10m), or
  - b) boundary does not provide sufficient dielectric contrast to produce an echo.
- Preferred interpretation is a) above, because a thick debris layer is unlikely to be low enough in density (source is mass wasted bedrock; compaction of thick layer will increase density).
- Best current estimate of overburden thickness is 1-10 m.



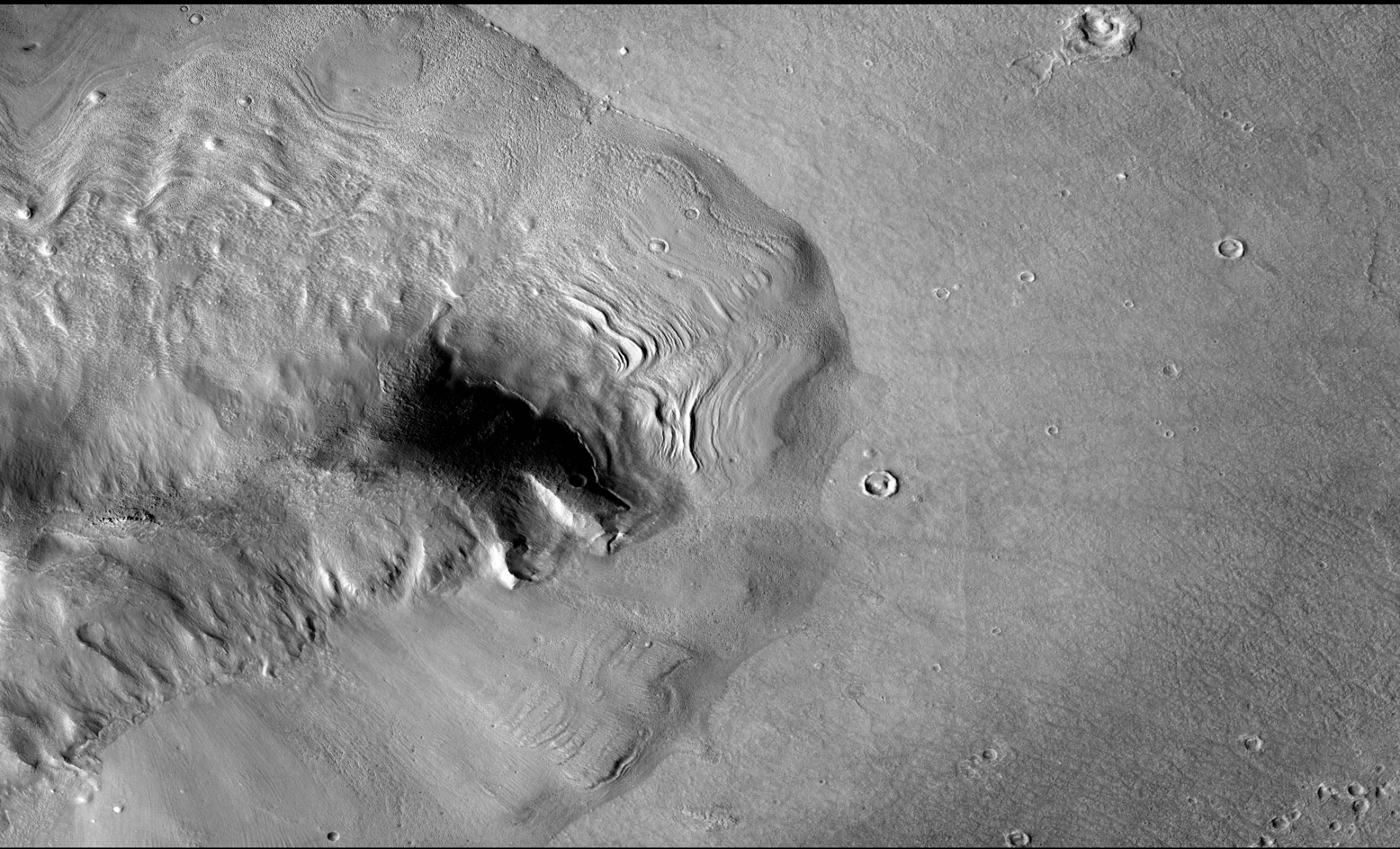






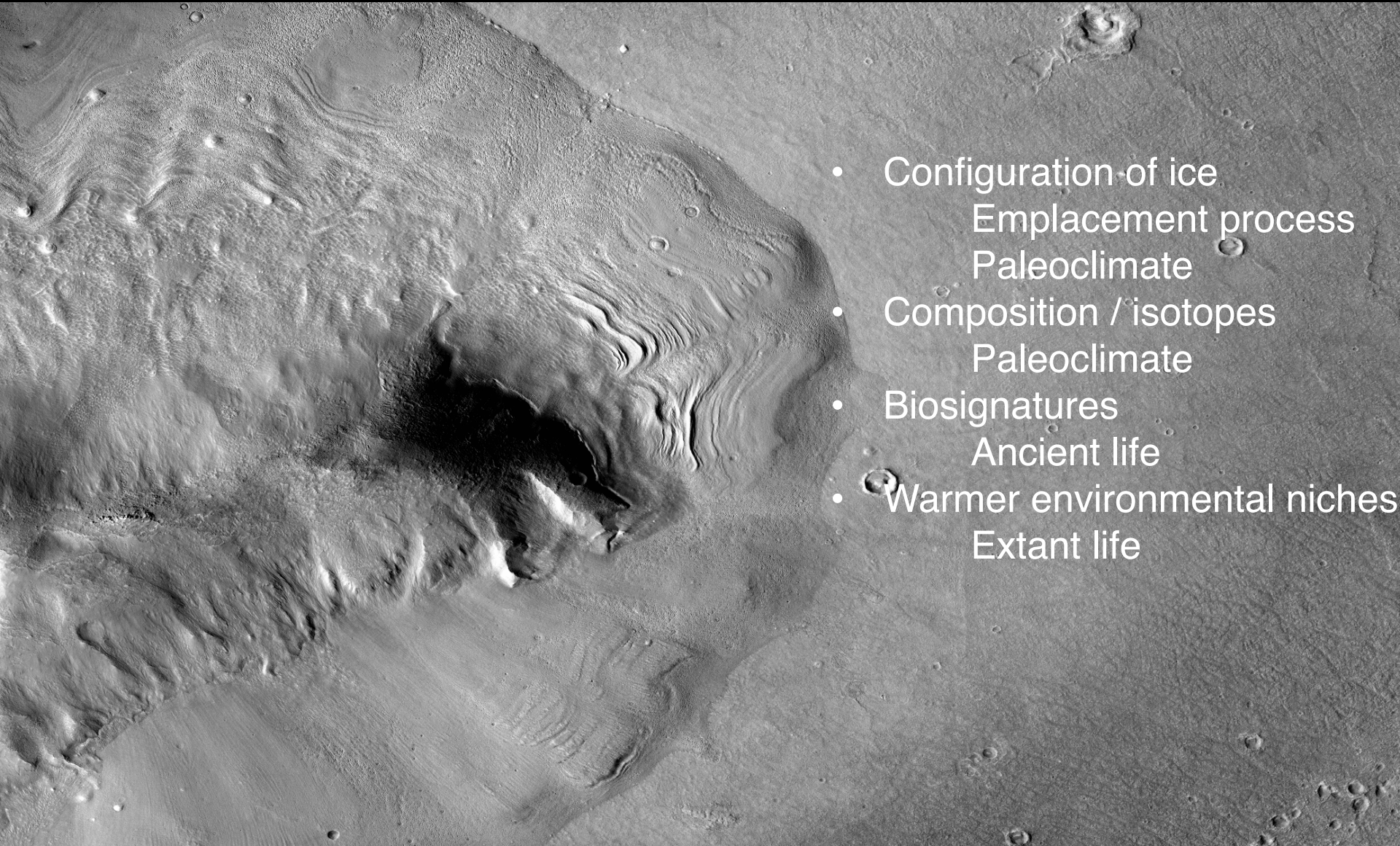


## Science ROI 1 – Margin of Apron





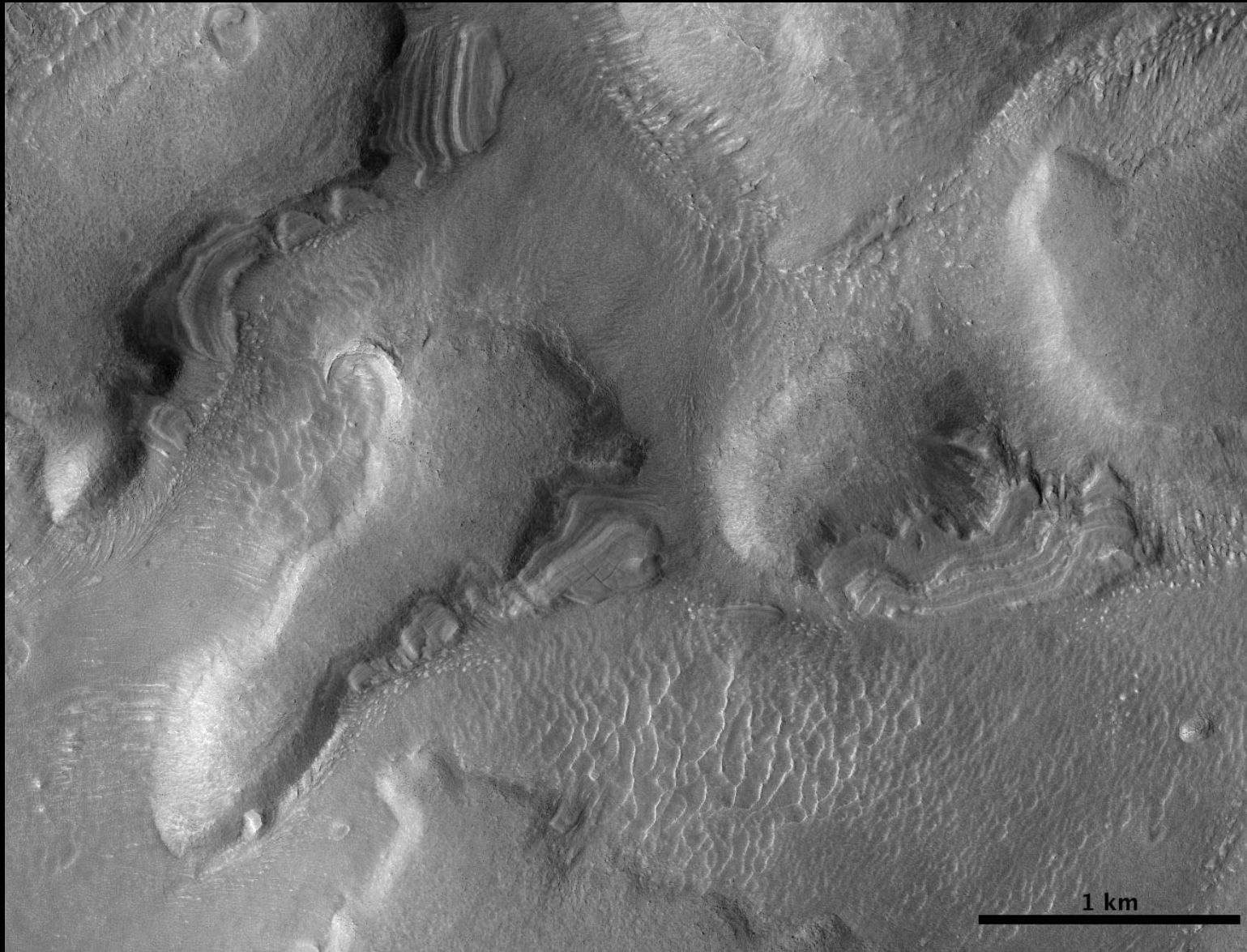
## Science ROI 1 – Margin of Apron



- Configuration of ice  
Emplacement process  
Paleoclimate
- Composition / isotopes  
Paleoclimate
- Biosignatures  
Ancient life
- Warmer environmental niches  
Extant life

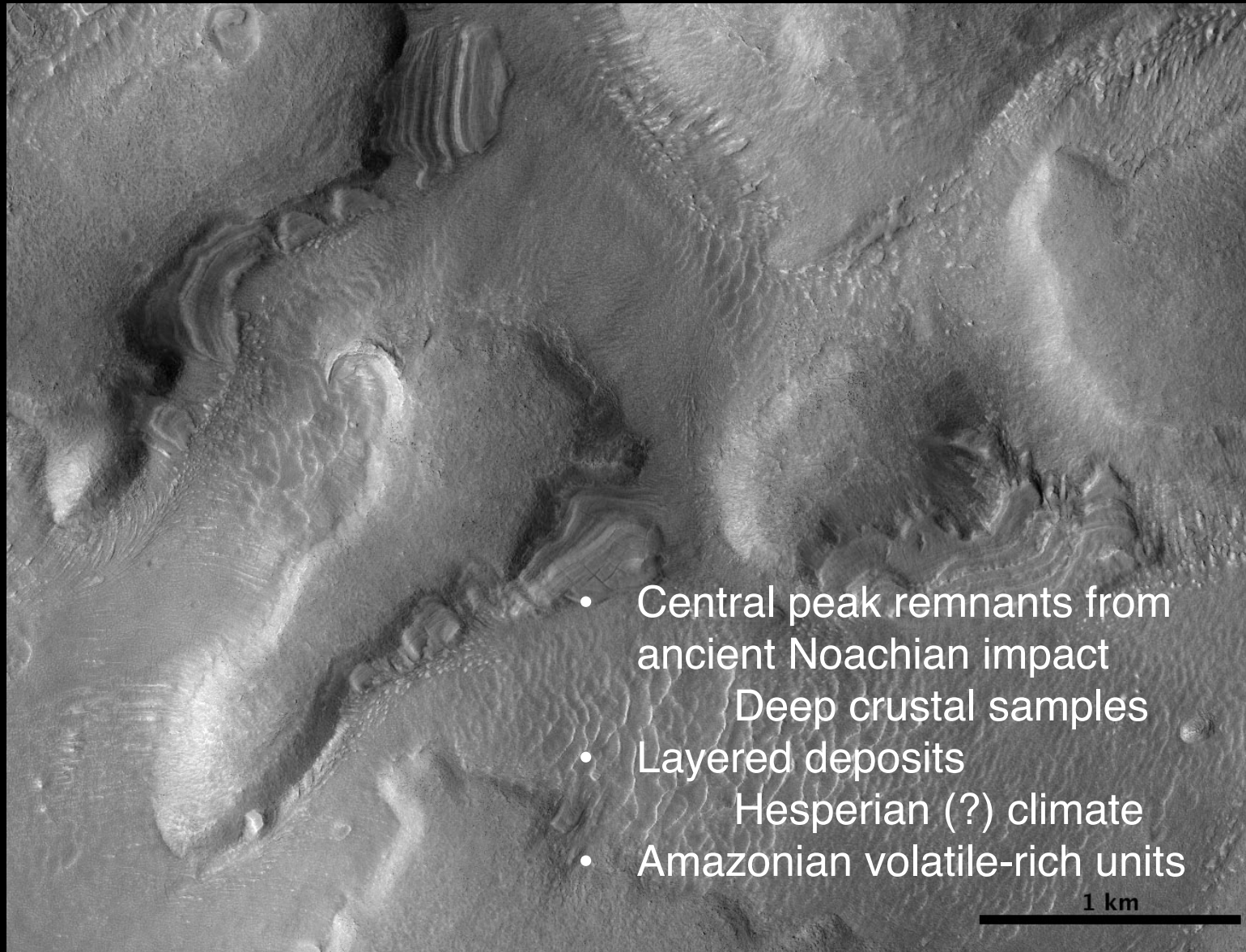


## Science ROI 2 – Colles Knobs and Layered Deposits





## Science ROI 2 – Colles Knobs and Layered Deposits



- Central peak remnants from ancient Noachian impact
  - Deep crustal samples
- Layered deposits
  - Hesperian (?) climate
- Amazonian volatile-rich units

1 km

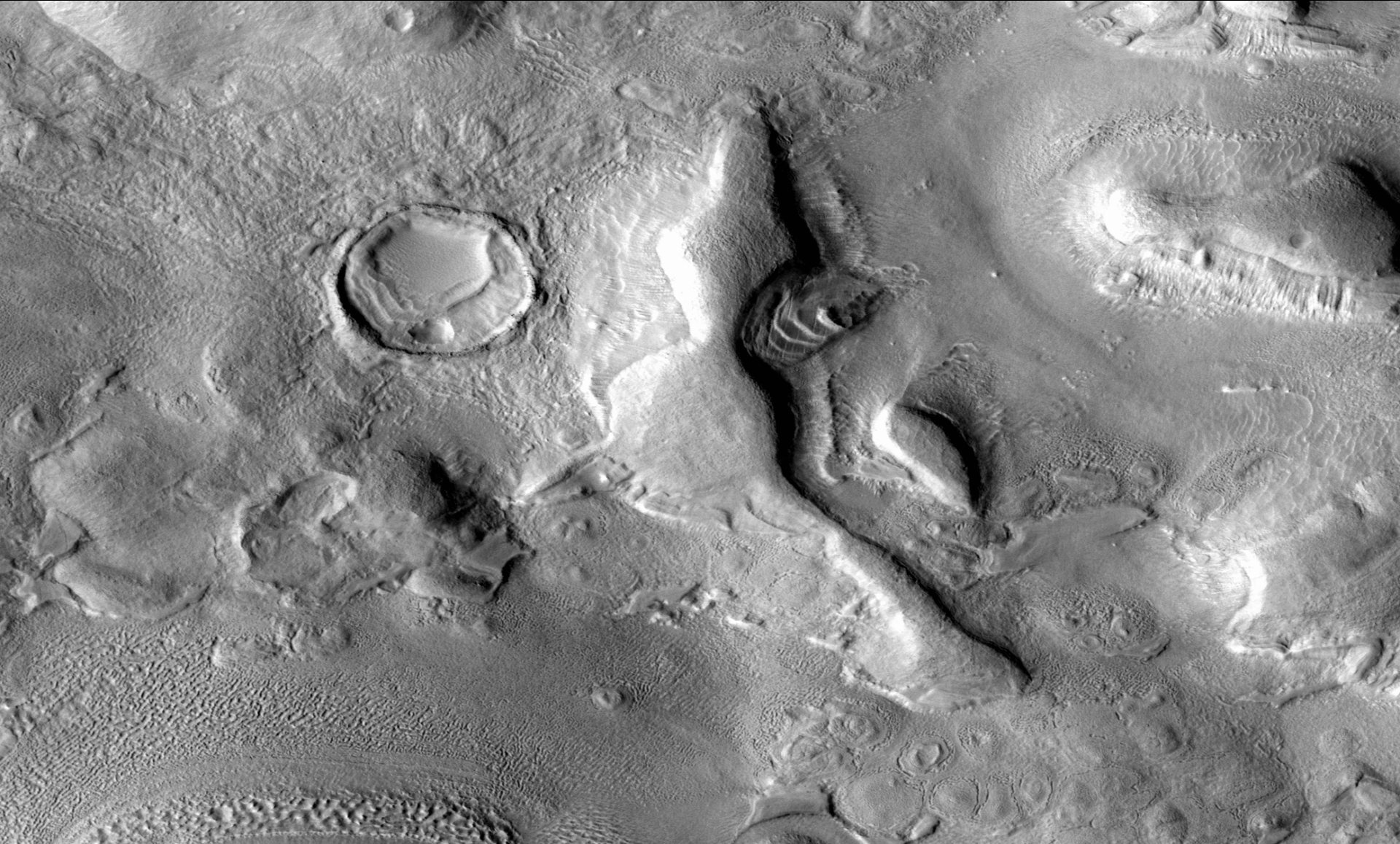


## Science ROI 2 – Colles Knobs and Layered Deposits



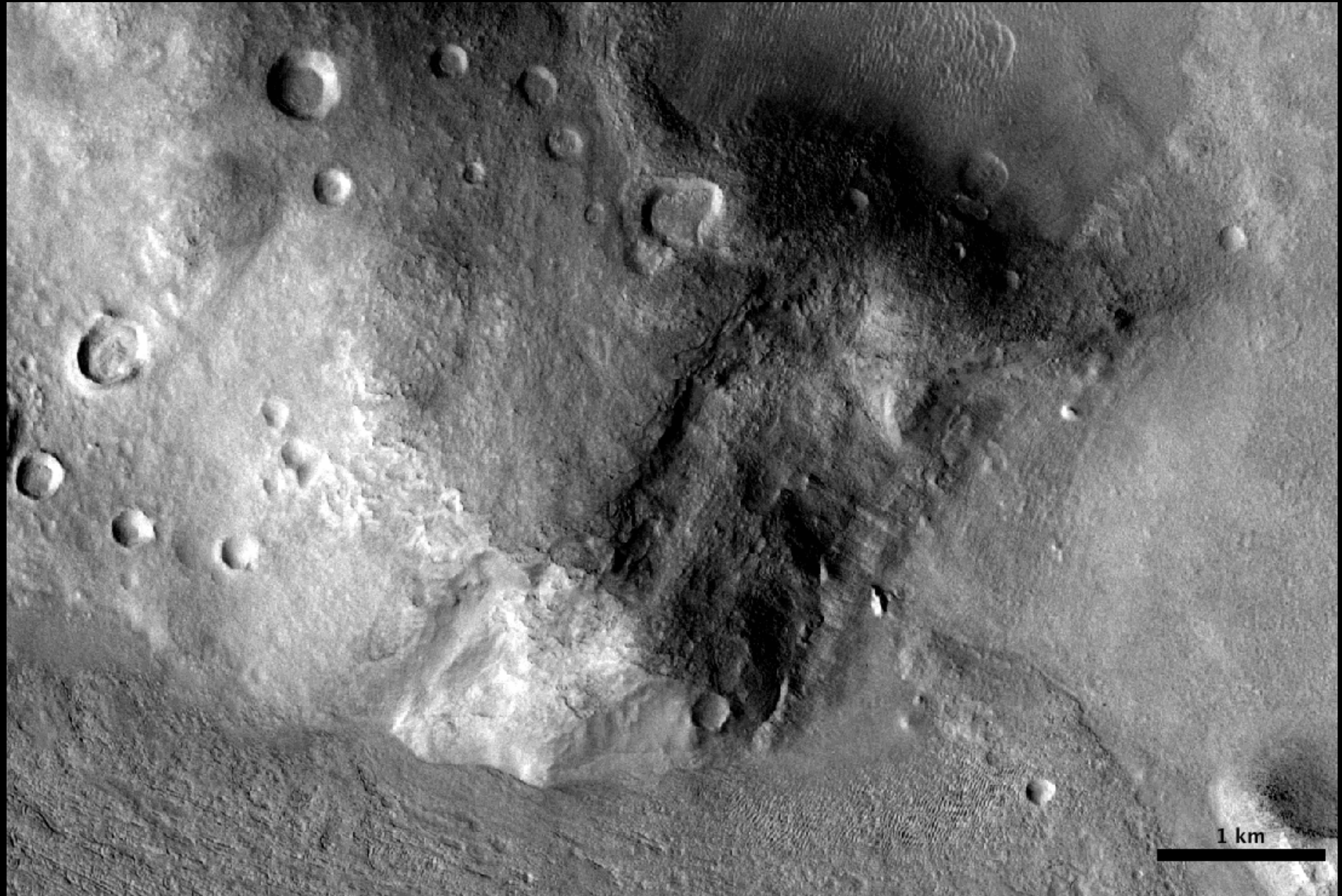


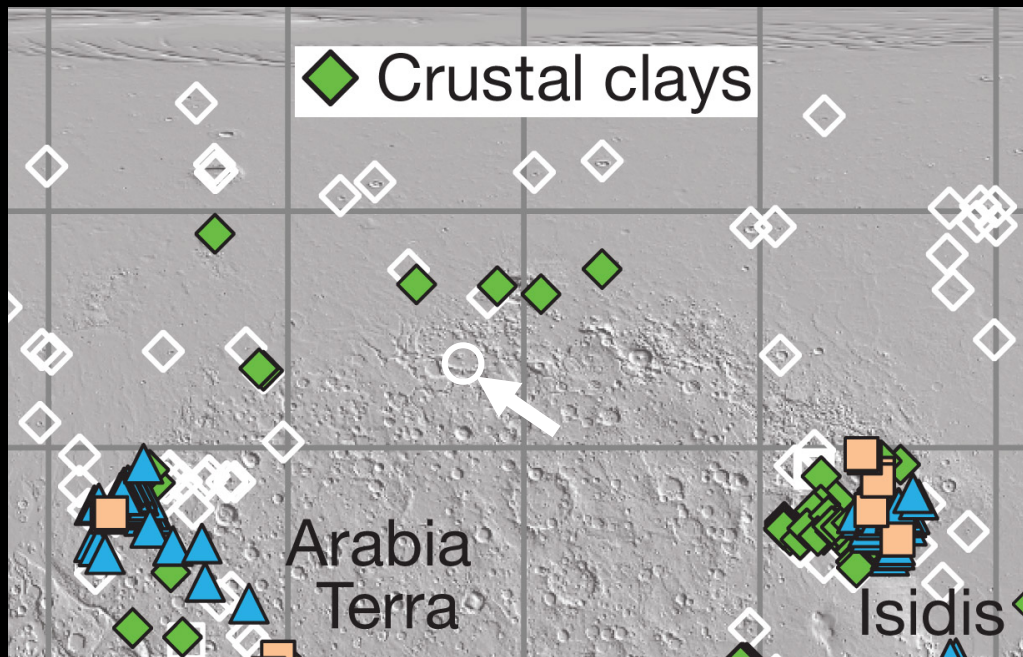
## Science ROI 2 – Colles Knobs and Layered Deposits





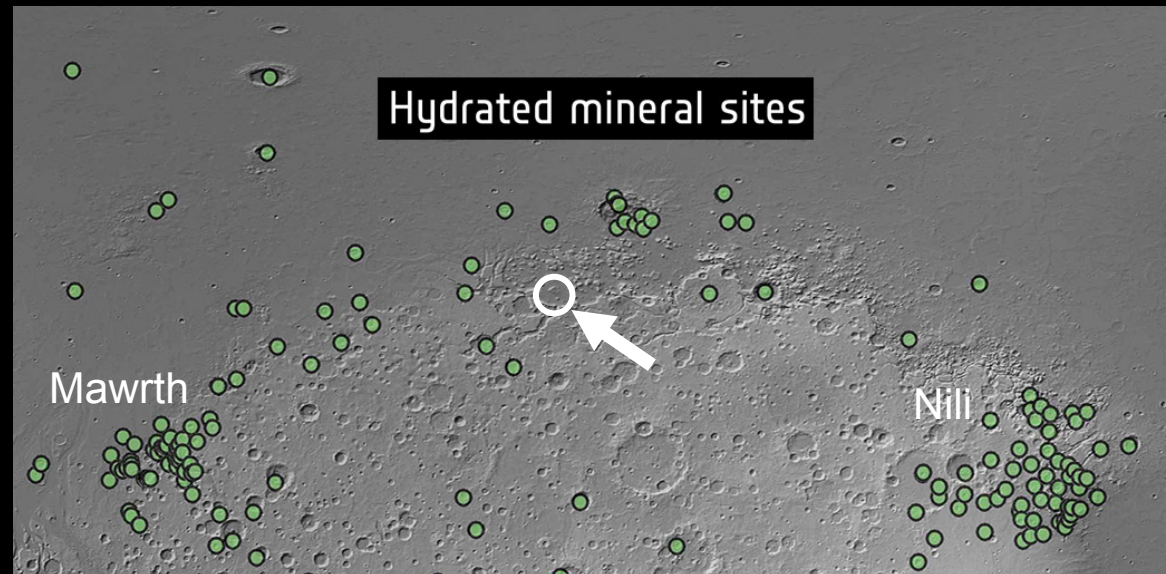
## Science ROI 3 – Noachian Terrains at Dichotomy Boundary





Clays and other hydrated minerals detected in Noachian terrains at the Dichotomy Boundary

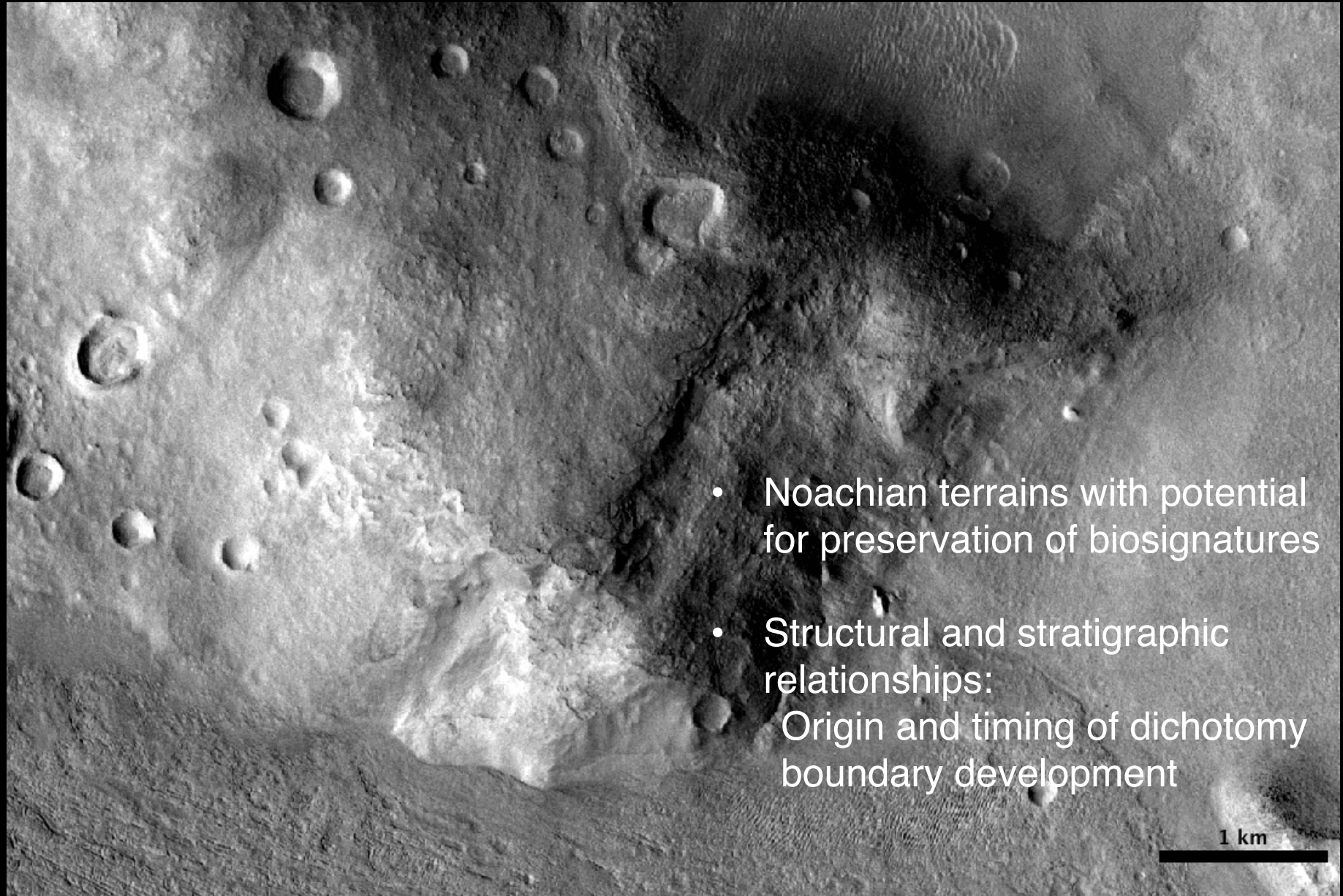
Ehlman et al., 2011



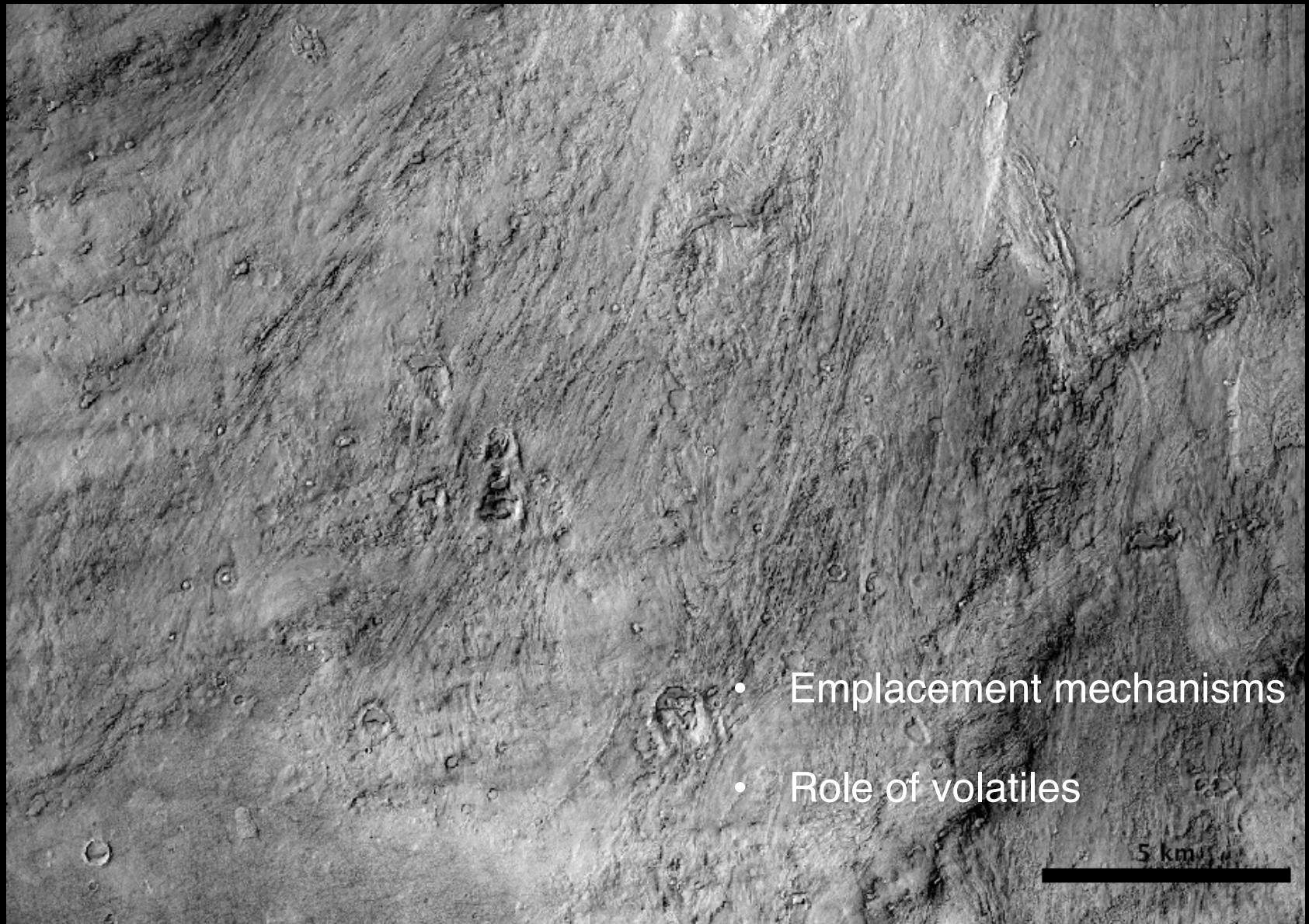
ESA image release  
(Carter et al., 2013)



## Science ROI 3 – Noachian Terrains at Dichotomy Boundary



## Science ROI 4 – Impact with Multiple Layer Ejecta





# Resource ROIs Rubric

1<sup>st</sup> EZ Workshop for Human Missions to Mars



Site Factors					RROI1
ISRU and Civil Engineering Criteria	Engineering		Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)		●
	Water Resource	Threshold	AND/ OR	Potential for ice or ice/regolith mix	●
				Potential for hydrated minerals	○
			Quantity for substantial production	●	
			Potential to be minable by highly automated systems	●	
			Located less than 3 km from processing equipment site	●	
			Located no more than 3 meters below the surface	○	
			Accessible by automated systems	●	
		Qualifying	Potential for multiple sources of ice, ice/regolith mix <b>and</b> hydrated minerals		●
			Distance to resource location can be >5 km		N/A
			Route to resource location must be (plausibly) traversable		●
	Civil Engineering	Threshold	~50 sq km region of flat and stable terrain with sparse rock distribution		●
			1–10 km length scale: <10°		●
			Located within 5 km of landing site location		●
		Qualifying	Located in the northern hemisphere		●
			Evidence of abundant cobble sized or smaller rocks and bulk, loose regolith		○
			Utilitarian terrain features		?
	Food Production	Qualifying	Low latitude		
			No local terrain feature(s) that could shadow light collection facilities		●
			Access to water		●
			Access to dark, minimally altered basaltic sands		○
	Metal/Silicon Resource	Threshold	Potential for metal/silicon		?
			Potential to be minable by highly automated systems		?
			Located less than 3 km from processing equipment site		?
			Located no more than 3 meters below the surface		?
			Accessible by automated systems		?
		Qualifying	Potential for multiple sources of metals/silicon		?
			Distance to resource location can be >5 km		?
			Route to resource location must be (plausibly) traversable		?

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

ISRU and Civil Engineering Criteria	Engineering		Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)		●
	Water Resource	Threshold	AND/OR	Potential for ice or ice/regolith mix	●
				Potential for hydrated minerals	○
			Quantity for substantial production		●
			Potential to be minable by highly automated systems		●
			Located less than 3 km from processing equipment site		●
			Located no more than 3 meters below the surface		○
			Accessible by automated systems		●
		Qualifying	Potential for multiple sources of ice, ice/regolith mix <b>and</b> hydrated minerals		●
			Distance to resource location can be >5 km		N/A
			Route to resource location must be (plausibly) traversable		●
	Civil Engineering	Threshold	~50 sq km region of flat and stable terrain with sparse rock distribution		●
			1–10 km length scale: <10°		●
			Located within 5 km of landing site location		●
		Qualifying	Located in the northern hemisphere		●
			Evidence of abundant cobble sized or smaller rocks and bulk, loose regolith		○
			Utilitarian terrain features		?
	Food Production	Qualifying	Low latitude		
			No local terrain feature(s) that could shadow light collection facilities		●
			Access to water		●
			Access to dark, minimally altered basaltic sands		○
	Silicon Resource	Threshold	Potential for metal/silicon		?
			Potential to be minable by highly automated systems		?
			Located less than 3 km from processing equipment site		?
			Located no more than 3 meters below the surface		?
			Accessible by automated systems		?
			Potential for metal/silicon		



# Science ROIs Rubric

1<sup>st</sup> EZ Workshop for Human Missions to Mars



Site Factors					SROI1	SROI2	SROI3	SROI4
Science Site Criteria	Astrobio	Threshold	AND/OR	Potential for past habitability	●	●		
				Potential for present habitability/refugia	●	●		
		Qualifying		Potential for organic matter, w/ surface exposure				
	Atmospheric Science	Threshold		Noachian/Hesperian rocks w/ trapped atmospheric gases		●	●	●
		Qualifying		Meteorological diversity in space and time	●	●		
				High likelihood of surface-atmosphere exchange	●	●		●
				Amazonian subsurface or high-latitude ice or sediment	●			
				High likelihood of active trace gas sources				
	Geoscience	Threshold		Range of martian geologic time; datable surfaces		●	●	●
				Evidence of aqueous processes	●	●	●	●
				Potential for interpreting relative ages	●	●	●	
		Qualifying		Igneous Rocks tied to 1+ provinces or different times				
				Near-surface ice, glacial or permafrost	●	●		
				Noachian or pre-Noachian bedrock units		●	●	
				Outcrops with remnant magnetization				
				Primary, secondary, and basin-forming impact deposits				●
				Structural features with regional or global context		●	●	
				Diversity of aeolian sediments and/or landforms				

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

# Highest Priority EZ Data Needs

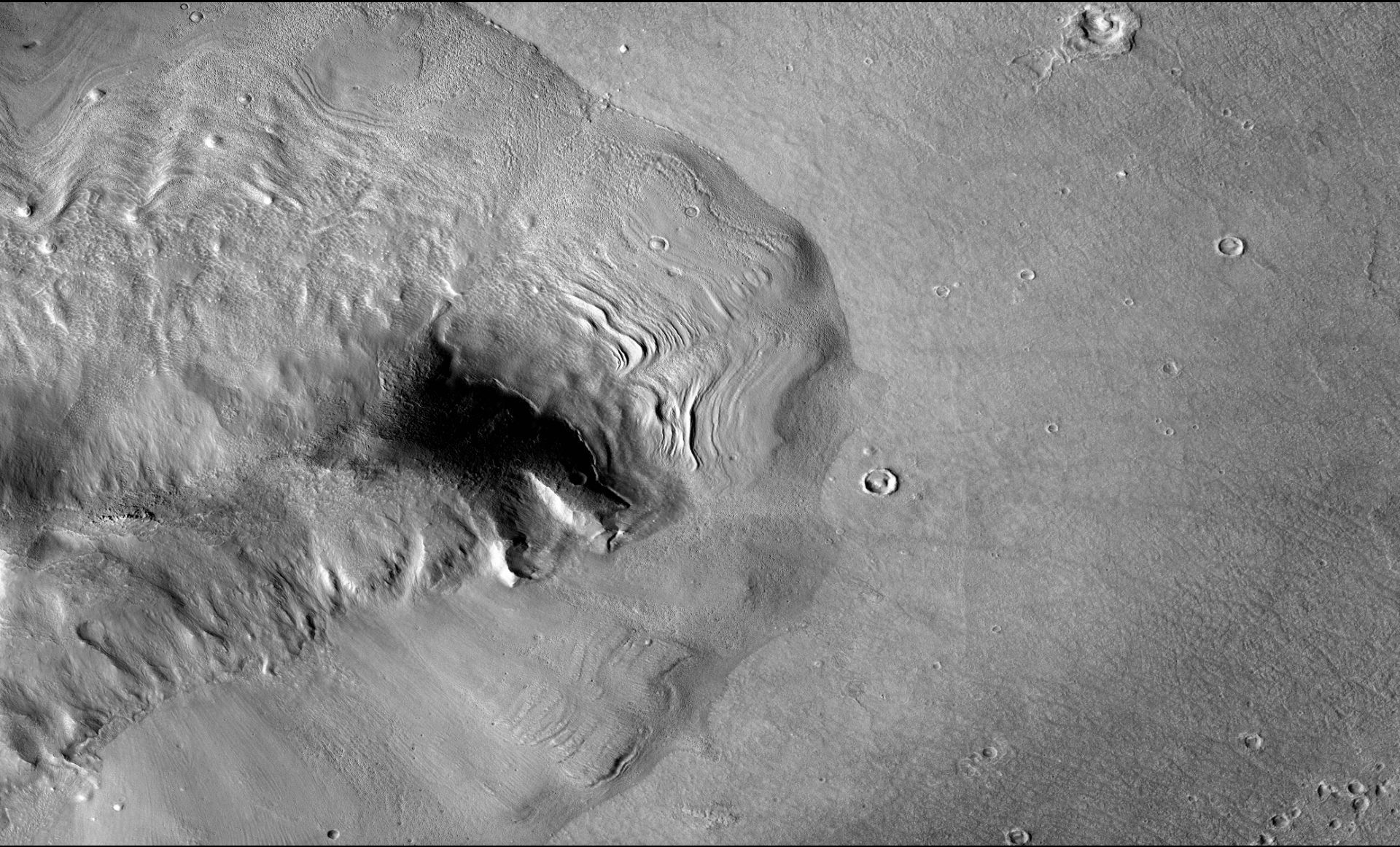
1<sup>st</sup> EZ Workshop for Human Missions to Mars

- What is the single most important additional data set needed to assess the science potential of the EZ?
- What is the single most important additional data set needed to assess the resource potential of the EZ?

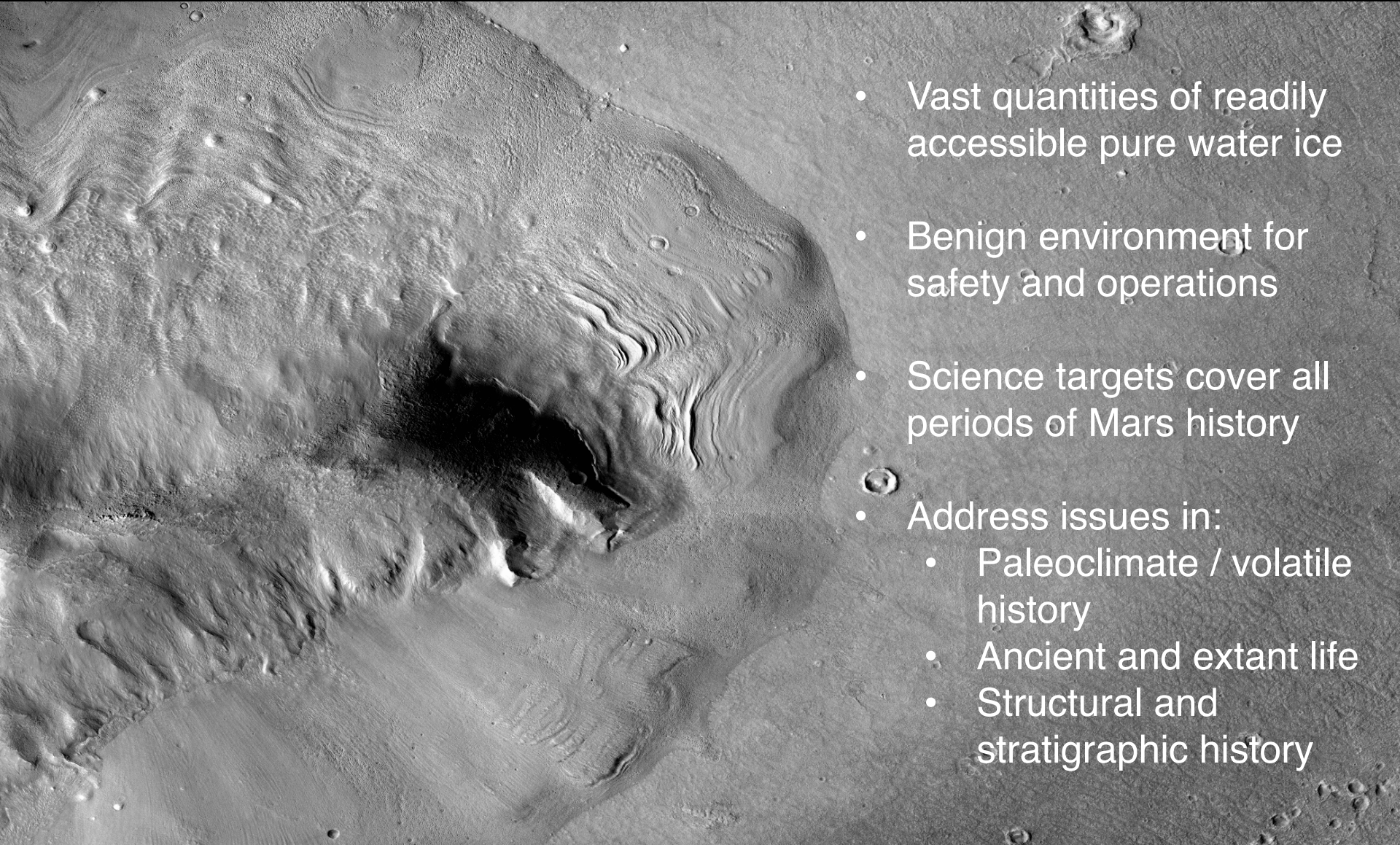
HiRISE imagery, including stereo, of the LDA margin areas that would be access points for resource and science sampling.



# Summary



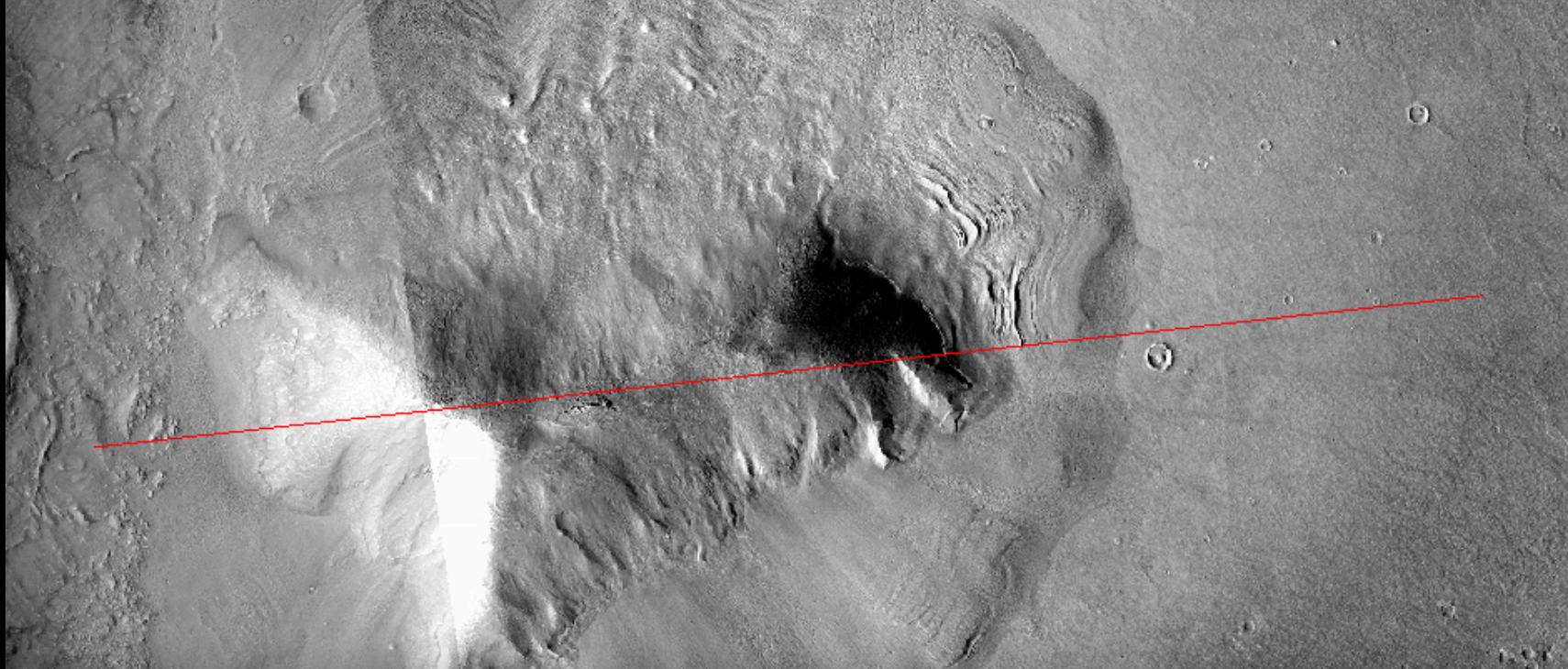
# Summary



- Vast quantities of readily accessible pure water ice
- Benign environment for safety and operations
- Science targets cover all periods of Mars history
- Address issues in:
  - Paleoclimate / volatile history
  - Ancient and extant life
  - Structural and stratigraphic history

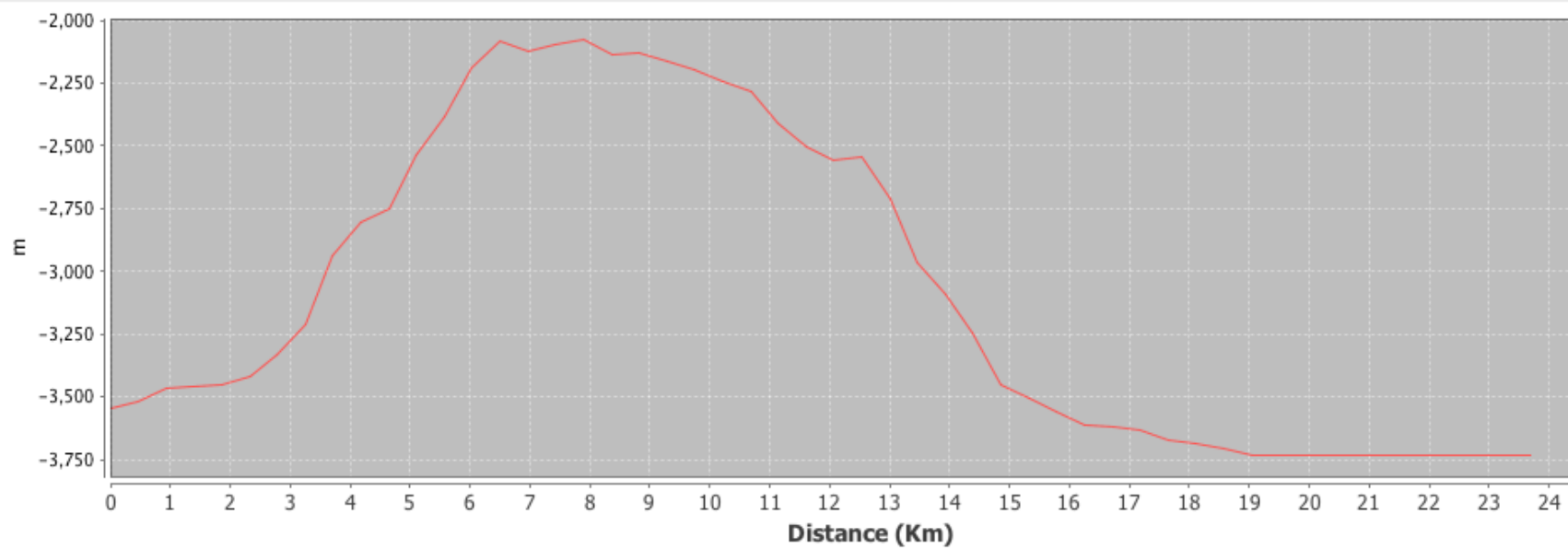




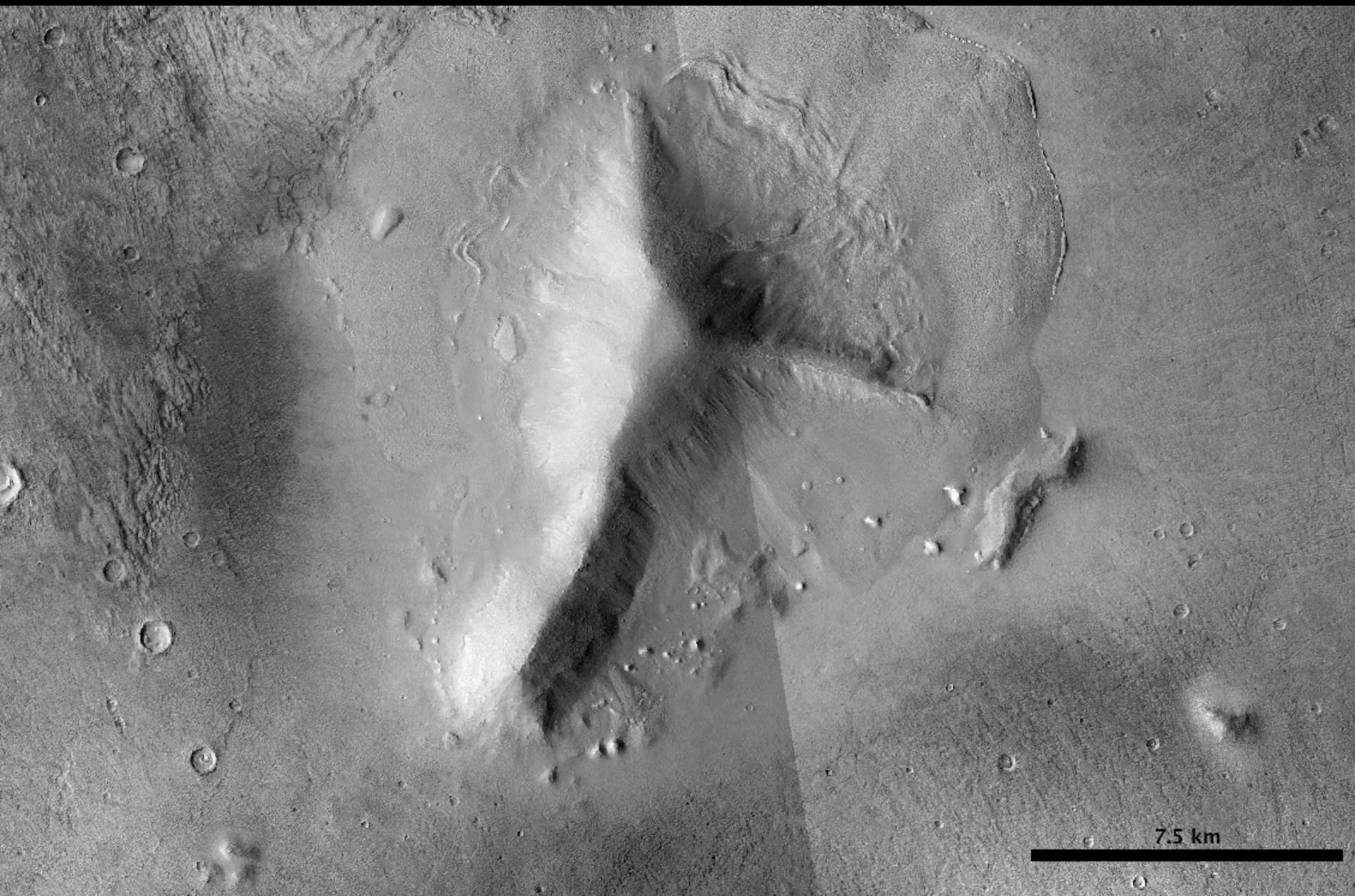


MOLA 128ppd Elevation Options

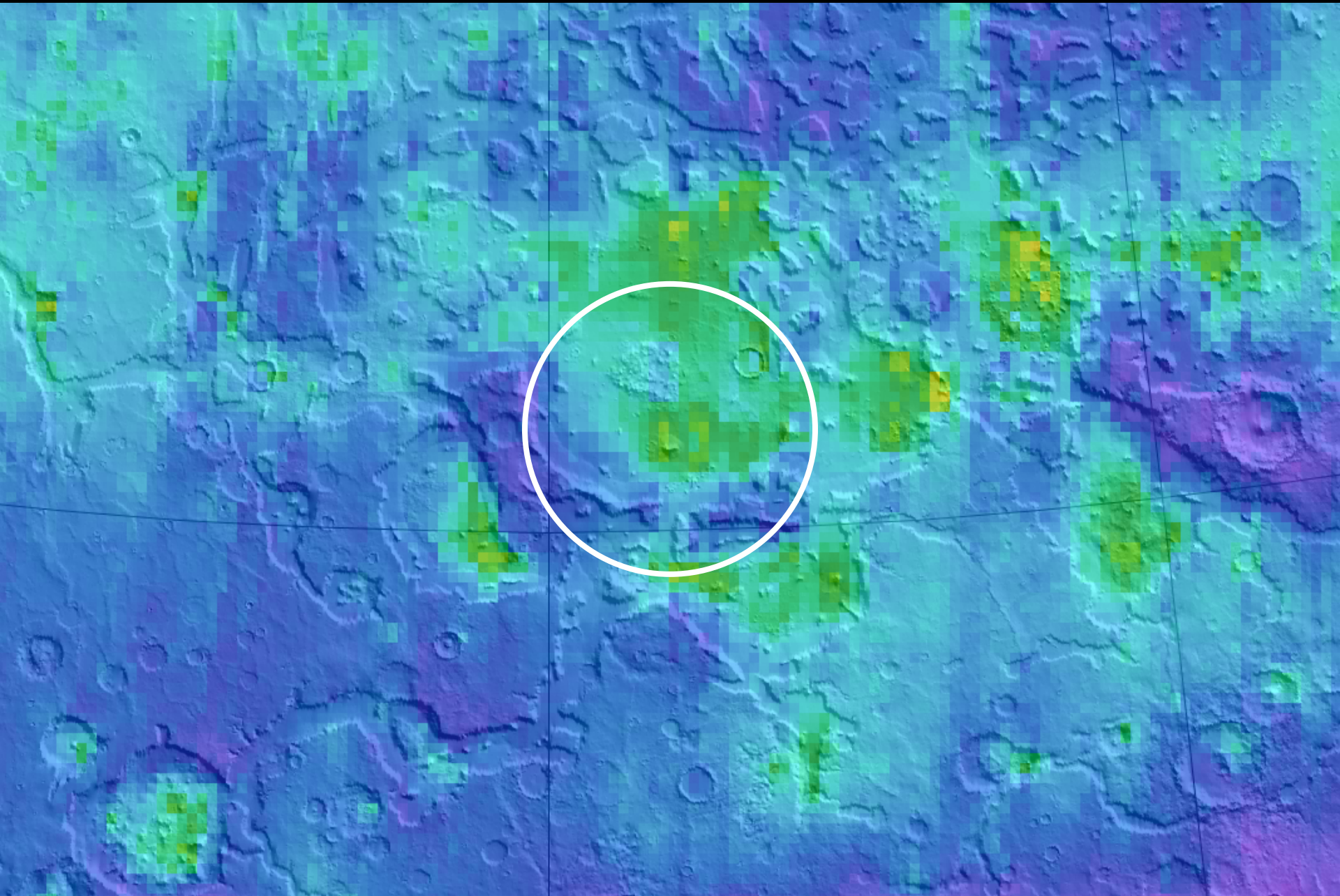
Chart PPD: 128







# TES Thermal Inertia – Range 100-300 TI Units





# THEMIS Night IR (color) Over Day IR Image

